DRAFT
Demonstration of Substantial and Widespread Economic Impacts to Montana That Would Result if Base Numeric Nutrient Standards had to be Met by Entities in the Private Sector in 2011/2012

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ACRONYMS

Acronym	Definition
AFDW	Ash Free Dry Weight
AWTF	Advanced Water Treatment Facility
BAT	Best Available Technology
BBER	Bureau of Business and Economic Research
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BPD	Barrels Per Day
CAFO	Concentrated (or Confined) Animal Feed Operations
DEQ	Department of Environmental Quality (Montana)
EBNR	Enhances Biological Nutrient Reduction
EPA	Environmental Protection Agency (US)
FO	Forward Osmosis
GDP	Gross Domestic Product
GHG	Green House Gas
IR	Integrated Report
MCA	Montana Code Annotated
MCF	Million Cubic Feet
ME-RO	Microfiltration-Reverse Osmosis (ME-RO)
MF	MicrofiltrationF
MGD	Million Gallons Per Day
MT DEQ	Montana Department of Environmental Quality
MW	Megawatts
NAICS	North American Industry Classification System
NF	Nanofiltration
NPDES	National Pollutant Discharge Elimination System
OG	Oil and Gas
REC	Reclamation Division (DEQ)
RO	Reverse Osmosis
SB	Senate Bill
SMC	Stillwater Mining Company
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
ULPRO	Ultra-Low Pressure Reverse Osmosis (ULPRO)
UV	Ultraviolet
WRP	Watershed Restoration Plan
WTF	Water Treatment Facility
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document quantifies the costs to affected Montana businesses of meeting the base numeric nutrient standards today, given the current state of treatment technology and the current economic status of the state. This paper demonstrates the substantial economic and social impacts of meeting nutrient criteria to 50 or so affected businesses in Montana and to those who depend upon the businesses for jobs, purchases, commodities, secondary spending, etc. It also looks at widespread effects on the state of Montana as a whole. This document provides DEQ's analyses and conclusions supporting the statute language (§75-5-313[5], MCA (2011) that all private dischargers are, at the present time, exempt from meeting the base nutrient standards based on "Substantial and Widespread" economic impacts.

The EPA's 1995 Guidance offers steps that can be taken to determine substantial and widespread impacts of water quality standards on both public wastewater treatment plants and on private businesses. The guidance for public wastewater treatment plants is fairly straightforward, and was used by MT DEQ to demonstrate substantial and widespread impacts on the municipalities having to meet standards. The private guidance is not as straightforward and does not provide direct thresholds for the 'substantial' determination, as does the public guidance.

Therefore, this demonstration takes parts of the EPA Guidance and makes it part of a larger evaluation for assessing substantial and widespread impacts for private businesses and communities in Montana. For the purposes of this demonstration, 'substantial impacts' refers to financial and other impacts on affected businesses, and 'widespread impacts' refers to ripple effects within Montana from the business impacts. The widespread impacts were looked at both locally (e.g. the effect of a business closing on the town it resides in) and statewide (i.e. overall impacts on Montana taxes, energy supply). The major steps for this evaluation included the following: 1) define the businesses that would be affected, 2) define both the current treatment level for nutrients and the applicable criteria for each business, 3) estimate the costs of meeting the applicable base numeric criteria for each affect business, 4) estimate the financial impacts of these costs on the businesses themselves, and 5) estimate the widespread ripple effects from the business impacts.

This demonstration is based upon best available information as it relates to each major step of the analysis. In addition, a sensitivity analysis is made around the estimated costs. It is DEQ's best professional judgment that the resulting costs of requiring immediate compliance with the base numeric nutrient criteria would result in substantial costs beyond what individual firms can internalize, and that this in turn would lead to widespread impacts.

BACKGROUND

The Montana Department of Environmental Quality (DEQ) began developing numeric nutrient standards for state surface waters in 2001. A field pilot study was undertaken from 2001-2003 to identify and refine approaches for developing the criteria in the plains region of the state. Work from 2003-2008 focused on the selection of an appropriate zoning system by which the criteria would be applied, collection of data from reference streams to help with criteria derivation, and identification of harm-to-use thresholds for beneficial water uses that nutrients affect. During this same period DEQ undertook a focused data collection to support the QUAL2K water-quality model which was then used to develop numeric nutrient criteria for a large river (lower Yellowstone). In addition, DEQ collected data to support lake nutrient standards (this work in ongoing, as are other field projects intended to further refine the flowing-water criteria).

In 2008, DEQ released draft nutrient criteria for wadeable streams (Suplee, et al., 2008) and presented these to stakeholders. DEQ has subsequently refined the process by which wadeable stream criteria are derived, and is in the process of preparing those as of this writing; draft values are shown below (**Table 1**) along with draft criteria for the lower Yellowstone River. In **Table 1** and throughout this analysis, the N stands for nitrogen and the P for phosphorus. While stakeholders understand that the criteria were derived based on sound science and reflect societal values that are protective of the designated water uses, the proposed criteria are stringent (**Table 1**). As a result, the stakeholder community has been concerned about what their permit limits will be as well as the opportunities for temporary variances from those stringent limits. Many permitted businesses discharging into wadeable streams do not have instream dilution and would be required to meet the nutrient criteria end-of-pipe. This likely includes businesses on the Yellowstone River between Laurel and Billings, which are assumed to have to meet end-of-pipe standards.

Table 1. Montana Draft Nutrient Criteria

Level III Ecoregion	Period When Criteria Apply	Parameter		
		Total P (mg/L)	Total N (mg/L)	Benthic Algae Criteria
Northern Rockies	July 1 -Sept. 30	0.025	0.3	120 mg Chl *a*/m^2 (36 g AFDW/m^2)
Canadian Rockies	July 1 -Sept. 30	0.025	0.3	120 mg Chl *a*/m^2 (36 g AFDW/m^2)
Middle Rockies	July 1 -Sept. 30	0.030	0.3	120 mg Chl *a*/m^2 (36 g AFDW/m^2)
Idaho Batholith	July 1 -Sept. 30	0.030	0.3	120 mg Chl *a*/m^2 (36 g AFDW/m^2)
Northwestern Glaciated Plains	June 16-Sept. 30	0.12	1.1	n/a
Northwestern Great Plains, Wyoming Basin	July 1 -Sept. 30	0.12	1.0	n/a
Yellowstone River (Bighorn R. confluence to Powder R. confluence)	Aug 1 -Oct 31	0.09	0.70	Nutrient concentrations based on limiting pH impacts
Yellowstone River (Powder R. confluence to stateline)	Aug 1 -Oct 31	0.14	1.0	Nutrient concentrations based on limiting nuisance algal growth

(Suplee, et al., 2008)

Due to the difficulty of meeting the draft numeric nutrient criteria at the present time, Montana Senate Bill 367 was signed by Governor Schweitzer on April 21, 2011. Senate Bill 367 (now (§75-5-313, MCA) authorizes individual, general and alternative variances. Under the general variance limits established in (§75-5-313, MCA), permit limits would be established based on 1 mg/L TP and 10 mg/L TN for facilities discharging $\geq$ 1 MGD, or 2 mg/L TP and 15 mg/L TN for facilities discharging $\leq$ 1 MGD. Facilities with lagoons would be capped at their current nutrient load. Over the next 20 years, as treatment technology improves and costs come down, more stringent nutrient levels for the general variance will very likely be required. As mentioned above, the present document provides DEQ's demonstration supporting the statute language that all private dischargers are, at the present time, exempt from meeting the base nutrient standards based on "Substantial and Widespread" economic impacts.

MONTANA'S PRIVATE BUSINESSES

Out of the thousands of businesses in Montana, about 50 were identified as ones that would be affected by the nutrient criteria. Included were businesses that have a discharge permit into state waters, and are not otherwise hooked up to a municipal system. Therefore, the numeric nutrient water quality standards only apply to business entities that have a surface water discharge permit.

Of the approximately 75 private businesses with a Montana Pollutant Discharge Elimination System permit, there are approximately 65 that may be subject to the numeric nutrient water quality standards. There are some private dischargers that would not have a reasonable potential to exceed the nutrient water quality standards because either the discharged wastewater does not contain either TP or TN, because the discharge is only non-contact cooling water or other process wastewater, or that nutrients are not a parameter of concern. The cost analysis began with a list of 74 NPDES permit numbers. Of those, 2 were for the CAFO general permit, 5 were considered terminated and sent to archives, 4 had not yet been issued, 2 were pending, and 2 others were excluded because it was hard to say what their operation consisted of. Of the remaining 59 permits within the analysis, 6 were considered to not have nutrients in their effluent, one was moving to a non-discharging system and one is a draft permit for a proposed facility. That left 51 NPDES permits that could be used for this demonstration.

The 51 businesses range from very large companies, employing over 1,000 people (e.g., Stillwater/East Boulder Mine), to very small, family owned businesses (e.g., Sleeping Buffalo Hot Springs). These businesses are in the following sectors:

- Metal mining (6)
- Coal Mining (9)
- Electric Generation (3)
- Oil and gas production (5)
- Refineries (4)
- Manufacturing including talc, silicon, cement, and chemicals (13)
- 'Other businesses' including hot springs, train yards, health care, sugar plants, livestock, and a boys and girls ranch (11)

These businesses tend to be located near Montana's seven large towns, with the largest number being in Billings. However, some are located in remote areas and the affected businesses are spread geographically across the state. The largest affected businesses are in the central and south central portions of Montana. The majority of businesses on the list are core Montana industries that generally pay higher than average wages, and in certain cases, supply crucial economic goods to Montanans and others out of state. The most crucial of these to the overall functioning of the Montana economy are the three affected refineries in or near Billings. They provide almost all of Montana's liquid petroleum products as well as about 50% of Spokane's and 30% of North Dakota's. In addition, the Stillwater mine, consisting of two primary mines, is one of the only sources of palladium and platinum in North America (although we are focusing on Montana impacts in this demonstration). In addition, Montana's coal resources supply over 60% of Montana's electricity generation (100% of its coal-based electricity generation) and supply coal to more than 10 other states for the purpose of electricity generation.

CURRENT TREATMENT LEVELS FOR NUTRIENT REMOVAL AND APPLICABLE CRITERIA FOR EACH BUSINESS

Data Gathering

DEQ and a contractor examined the wastewater permits and the Statement of Basis for each of the 51 affected businesses. These records are located within DEQ's Permitting Division. Within each permit, DEQ collected the following information where available:

- Current level of water treatment technology
- Measured effluent data from the business (including nutrient levels)
- Name and status of the receiving stream
- The dilution potential for the effluent given the receiving stream

From this data, DEQ and the contractor calculated the applicable nutrient criteria for each of the businesses depending upon their location in Montana, dilution potential, etc. The nutrient criteria that a particular business would have to meet would depend on how much dilution the receiving stream has for their effluent, and where the business is located in state (the specific ecoregion). For most businesses, nutrient effluent levels were not available, so DEQ used a method for many businesses to 'back out' current nutrient effluent levels. For most businesses, current effluent level (including TN and TP) was determined by the description of the current treatment system included in their NPDES permits and supplemented by past monitoring data included in their most recent permit.

To estimate costs to each business of meeting nutrient criteria, DEQ relied on a study that looked at costs associated with removing nutrients from wastewater at 5 different levels of treatment (**Table 2**; (Falk, et al., 2011) (**Appendix C**). The DRAFT Interim WERF study "*Finding the Balance Between Wastewater Treatment Nutrient Removal and Sustainability, Considering Capital and Operating Costs, Energy, Air and Water Quality and More*" (Falk, et al., 2011) looked at different levels of nutrient treatment ranging from minimal treatment (level 1) to a treatment that is close to

Montana's base criteria (level 5). WERF Level 1 treatment does not directly treat N and P, whereas Level 2 treatment is about the same as the general variance levels in Montana SB 367 mentioned above. The levels of treatment and associated costs in the WERF study are presented in **Table 2**. The technologies used at each level are presented in **Table 3**.

Table 2. Effluent Quality and Associated Treatment Costs in the Interim WERF study (Falk, et al., 2011; Tetra Tech, 2011)

Level	Description	Capital Cost (million dollars per 1 MGD design flow)	Operations Cost (dollars per day per 1 MGD actual flow)
Level 1	No N and P removal	9.3	250
Level 2	1 mg/l TP; 8 mg/l TN	12.7	350
Level 3	0.1-0.3 mg/l TP; 4-8 mg/l TN	14.4	640
Level 4	<0.1 mg/l TP; 3 mg/l TN	15.3	880
Level 5	<0.01 mg/l TP; 1 mg/l TN	21.8	1370
Level 5/100% RO	<0.01 mg/TP; <1 mg/l TN	28.3	1860

Table 3. Unit Processes per Treatment Level in WERF Study (Falk, et al., 2011)

Level	Liquid Treatment	Solids Treatment	Comment
1	Primary Clarifier Activated Sludge Disinfection Dechlorination	Gravity Belt Thickener Anaerobic Digestion with Cogen Centrifugation	Conventional Activated Sludge for BOD/TSS removal
2	Primary Clarifier Activated Sludge Alum (optional) Disinfection Dechlorination	Gravity Belt Thickener Anaerobic Digestion with Cogen Centrifugation	Nitrification/Denitrification and Biological Phosphorus Removal
3	Primary Clarifier Activated Sludge Methanol (optional) Alum (filtration) Filtration Disinfection Dechlorination	Gravity Belt Thickener Anaerobic Digestion with Cogen Centrifugation	Nitrification/Denitrification and Biological Phosphorus Removal and Filtration
4	Primary Clarifier Activated Sludge Methanol (optional) Alum/Polymer (Enhanced Settling) Enhanced Settling Filtration Disinfection Dechlorination	Fermentation Gravity Belt Thickener Anaerobic Digestion with Cogen Centrifugation	Nitrification/Denitrification and Biological Phosphorus Removal, High Rate Clarification and Denitrification Filtration

5	Primary Clarifier Activated Sludge Methanol (optional) Alum/Polymer (Enhanced Settling) Enhanced Settling Filtration Microfiltration Reverse Osmosis Disinfection Dechlorination	Gravity Belt Thickener Anaerobic Digestion with Cogen Centrifugation	Nitrification/Denitrification and Biological Phosphorus Removal, High Rate Clarification, Denitrification Filtration, and MF/RO on about Half the Flow

The current treatment level distribution for those Montana dischargers with sufficient information to make a determination of level of treatment (32 of the 51 businesses) was 47% (WERF) level 1, 3% Level 2, 22% Level 3, 19% level 4, and 9% level 5 (without RO, or with RO as a backup). For businesses where the information in their permit was not adequate to make a determination, DEQ assigned treatment level 3 as a conservative estimate for the analysis (in order to lessen the chance of overestimating costs and impacts to businesses—assuming an already high level of treatment being done by businesses lessens the cost estimate of them having to meet base numeric criteria).

COSTS TO PRIVATE BUSINESSES OF HAVING TO MEET BASE NUTRIENT CRITERIA

Several tables were created that estimate the cost for each affected business of meeting base numeric nutrient criteria. **Appendix A** presents an Excel spreadsheet developed to calculate the annualized capital and operations and maintenance costs (O&M) associated with meeting the base numeric nutrient standards for each of the 51 businesses (where flow data were available). Capital and O&M costs for attaining nutrient standards were estimated from the DRAFT Interim WERF study (Falk, et al., 2011). **Appendix B** documents all the underlying assumptions applied for this demonstration. In essence, the cost assumptions are mostly the same as those made in the Public demonstration.

Key Elements of the Cost Framework include the following:

- The treatment technology used to simulate costs to businesses consisted of advanced mechanical treatment combined with reverse osmosis (RO) (**Appendix D**). Treatment costs included those associated with nitrification/denitrification and biological phosphorus removal, high rate clarification, and denitrification filtration. Costs were estimated from the DRAFT Interim WERF study "*Finding the Balance Between Wastewater Treatment Nutrient Removal and Sustainability, Considering Capital and Operating Costs, Energy, Air and Water Quality and More*" (Falk, et al., 2011).
- Every business must use reverse osmosis (RO) on 100% percent of their effluent in order to get to the stringent base criteria. The Interim WERF study assumed RO treatment for 50 percent of effluent flow at the most stringent treatment 'level 5'. WERF Level 5 is not as stringent for N as Montana's base numeric criteria. At level 5, half of the effluent flow remained treated by processes equivalent to WERF Level 4 and the other half received an enhanced level of treatment (reverse osmosis or RO). To meet the MT base numeric nutrient criteria, DEQ calculated that the highest level of treatment is needed for 100 percent of the flow. Thus, cost estimates in this demonstration are based on providing RO treatment to 100 percent of flow. These cost estimates are thus marginally higher than WERF level 5 cost estimates (see **Table 2** below). While it may be possible that some facilities' waste streams and effluent levels do not require 100 percent RO treatment (due to dilution potential in the receiving water, and thus less stringent levels of needed treatment), simulating costs at 100 percent RO provides an upper bound estimate of the potential economic impact to businesses. The Interim WERF study data were adapted to estimate the cost of treating all flow by RO by isolating the marginal unit

processes used for Level 4 and Level 5 and calculating the cost for a treatment train with 100 percent RO. (Schmidt, 2010) [1]

- The 51 businesses analyzed are mostly in economic activities of commoditized goods and services with inelastic national or global cost curves that dictate their ability to adjust to changing production costs. Therefore, parent companies, where they exist, will likely not pay to meet nutrient criteria, and this analysis looks at 'plant level' data ---that is, the effects of the base criteria on the local business rather than the larger parent company, where it exists. For example, DEQ examines the cost effects on the Billings Exxon Refinery rather than on the Exxon Mobile Corporation as a whole.
- Because most of these industries involve nationally or internationally traded commodities, costs of meeting base numeric criteria will not be primarily shifted to consumers. Rather, the private businesses themselves will have to incur the majority of costs.
- Where available, plant level data is used for current costs, financial information, and effluent flow. For situations where information is limited, representative data is used from the U.S. Census of Manufacturing and other sources to estimate a range of financial information for the particular industry group in Montana within which the affected business belongs.
- Discount (Interest) Rate—In some cases, assuming a five percent interest rate, as in the EPA Guidance, may be an appropriate discount rate to annualize the capital costs of treating nutrients, but may not be appropriate for private sector capital markets. Additionally, there exists some uncertainty on the rate depending on the general economic conditions at the time the investment is required and the debt capacity and rating of the borrower. Costs estimates are developed for sensitivity analysis scenarios with both a five percent and seven percent discount (interest) rate.
- Labor Costs—For the sensitivity scenarios developed below, labor costs of 15 and 48 percent of capital costs were included in the total cost estimates. The original draft WERF study cost estimates used for this demonstration did not include labor costs, which can be a significant cost for a treatment process. This is the additional labor that would be needed to operate the new unit processes that would be installed, so it would be added on to O&M costs (yet is based on capital costs). An analysis of the life-cycle costs for a number of technologies used to control nitrogen and phosphorus in wastewater treatment plants estimated that labor costs are between 15-21 percent of the annualized capital costs for nitrogen and 15-48 percent of annualized capital costs for phosphorus.(Kang and Omstead, 2011)[2]
- Costs are under-estimated for small facilities and those with low flows, because the WERF cost data was multiplied by effluent flow providing a linear cost estimate based on flow. Clearly, there will be a minimum cost of treating to base nutrient standards for facilities with small flows such as pouring concrete, hiring labor, etc. that is greater than the linear cost estimates for these low-flow and small facilities. DEQ believes that small facilities could not afford RO or even mechanical treatment in many cases.

Current effluent nutrient levels and estimates of current treatment costs at the 51 businesses were compared to costs that would be needed to meet base numeric nutrient standards based on the WERF study. In this way, annual capital and operations costs needed for meeting base nutrient criteria (above current nutrient treatment costs) were applied to each business. In other words, existing water nutrient treatment costs for private businesses were subtracted from estimated costs to meet the base criteria, if some treatment of nutrients was already being done. If a business already met WERF level 2 nutrient levels, for example, then the level 2 costs for both capital and operations were subtracted from 100% RO costs (stricter than level 5) to arrive at the additional cost to meet the criteria.

[1] Schmidt, 2010 Shows that for TP, TN, and other micro-pollutants, RO was indeed the most effective method for removing TN and TP (better than membrane bioreactor, MBR). Thus, this study assumes the use of RO technology for this demonstration of economic hardship. (It is important to note that this does not mean that Montana WWTPs would be expected to implement RO to meet practical Limits of Technology [LOT] or nutrient criteria in practice.).

[2] Based on information in: Introduction of Nutrient Removal technologies Manual, EPA, 2008 and WEF/WERF Cooperative Study of Nutrient Removal Plants: Achievable Technology Performance Statistics for Low Effluent Limits)

A cost sensitivity analysis is conducted to account for differences in assumptions. As mentioned above, the operations costs of meeting base numeric criteria taken from the WERF study (**Table 3**) do not include labor and maintenance costs, so the costs estimates may be slightly low (conservative). This is addressed below in the cost sensitivity analysis. Discount rates may vary for borrowing money to meet the criteria. Also, WERF level 5 is not quite as stringent as the Montana base nutrient criteria for TN, so the costs to reach nutrient standards estimated for this demonstration are potentially underestimated in that sense as well. This is also addressed below in the cost sensitivity analysis.

Multiple estimated expected treatment costs were calculated based on six cost sensitivity scenarios (see **Table 4**). To reach these six scenarios, the discount (interest) rate was varied at 5 or 7 percent and the addition of both high (48 percent) and low (15 percent) labor costs as a percentage of capital costs were considered across each scenario.[3] Then, the 100% RO was added on to the original cost estimates separately to isolate how that assumption alone would affect costs.

Table 4. Scenarios for Sensitivity Analysis

Scenario	Description	Discount Rate	Labor Cost
Original	5% discount rate and 0% labor cost	5%	0%
Scenario A	Change of labor cost to 15% of capital cost	5%	15%
Scenario B	Change of labor cost to 48% of capital cost	5%	48%
Scenario C	Discount rate increase from 5% to 7% and 0% labor cost	7%	0%
Scenario D	Discount rate increase from 5% to 7% AND change of labor cost to 15% of capital cost	7%	15%
Scenario E	Discount rate increase from 5% to 7% AND change of labor cost to 48% of capital cost	7%	48%

COST RESULTS

Table 5 presents the estimated annual costs (annualized capital costs plus annual operation and maintenance costs) resulting from the installation of the additional water treatment controls to meet numeric nutrient criteria for each of the scenarios analyzed. Note that permittees with 'NA' as a cost estimate indicates those facilities without enough information to make a determination (i.e., no flow data available). **Table 5** shows the estimated average annual cost across all six scenarios for each affected business. It also shows which general business sector the individual business was categorized in (in bold italic type).

Table 5-Estimated Average Annual Costs (Capital and O&M Cost) for Affected Montana Businesses
(***Sector Codes: M-metal mining, C-Coal Mining, OG-Oil and Gas, E-Electric Generation, R-Refineries, Mfg-General Manufacturing, Oth-Other***)

Company (Sector code)	Original	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Cenex Refinery (***R***)	$4,644,227	$5,141,402	$6,235,188	$5,228,721	$5,813,570	$7,100,239
Conoco Refinery (***R***)	$5,682,449	$6,290,768	$7,629,070	$6,397,607	$7,113,200	$8,687,504
Burlington-Northern Railroad Whitefish Facility (***Oth***)	$152,129	$168,190	$203,525	$171,011	$189,904	$231,471
John R. Daily meat packing (***Oth***)	$475,402	$525,593	$636,015	$534,409	$593,451	$723,345
Montana Resources Inc. mine (Copper) (***M***)	$7,181,262	$7,969,886	$9,704,860	$8,108,392	$9,036,086	$11,077,012
Montana Sulfur and Chemical (***Mfg***)	$5,209,641	$5,759,662	$6,969,708	$5,856,262	$6,503,276	$7,926,708
Sidney Sugars Inc. (***Mfg***)	$2,777,137	$3,074,436	$3,728,493	$3,126,650	$3,476,376	$4,245,773
Western Sugar Cooperative (***Mfg***)	$19,995,386	$22,135,937	$26,845,150	$22,511,882	$25,029,908	$30,569,564
Montana Dakotas Utility-Lewis and Clark Electric generation plant (***E***)	$67,237,631	$74,336,416	$89,953,743	$75,583,176	$83,933,792	$102,305,148

3 DEQ first annualizes the capital cost and then multiplies it by the 15 or 48 percent factor.

Table 5-Estimated Average Annual Costs (Capital and O&M Cost) for Affected Montana Businesses
(***Sector Codes: M-metal mining, C-Coal Mining, OG-Oil and Gas, E-Electric Generation, R-Refineries, Mfg-General Manufacturing, Oth-Other***)

Company (Sector code)	Original	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Montana Rail Link—Livingston Rail Yard (***Oth***)	$225,911	$249,762	$302,234	$253,951	$282,008	$343,734
Corette electrical generation plant-PPL Montana (***E***)	$207,592,027	$229,509,086	$277,726,616	$233,358,378	$259,140,390	$315,860,816
Ash Grove Cement Company (***Mfg***)	$59,787	$66,099	$79,985	$67,207	$74,632	$90,968
Exxon-Mobile Refinery (***R***)	$5,767,900	$6,385,366	$7,743,793	$6,493,812	$7,220,166	$8,818,143
Trident Cement Plant (***Mfg***)	$13,154	$14,506	$17,480	$14,743	$16,334	$19,832
Big Sky Coal Company (***C***)	$4,825,326	$5,334,772	$6,455,554	$5,424,246	$6,023,530	$7,341,956
Decker Coal mine (west mine) (***C***)	$1,595,836	$1,771,086	$2,156,635	$1,801,865	$2,008,019	$2,461,558
Yellowstone Boys and Girls Ranch (***Oth***)	$42,725	$47,299	$57,361	$48,102	$53,483	$65,320
Absaloka Coal Mine (***C***)	$2,281,928	$2,522,848	$3,052,873	$2,565,161	$2,848,566	$3,472,058
MT Behavioral Health Inc WWTP (***Oth***)	$213,626	$236,495	$286,807	$240,512	$267,414	$326,598
Elkhorn Health Care WWTP (***Oth***)	$32,044	$35,474	$43,021	$36,077	$40,112	$48,990
Savage Coal Mine (***C***)	$912,771	$1,009,139	$1,221,149	$1,026,064	$1,139,426	$1,388,823
Boulder Hot Springs WWTP (***Oth***)	$134,697	$148,918	$180,204	$151,416	$168,145	$204,948
Rosebud Coal Mine (***C***)	NA	NA	NA	NA	NA	NA
Decker Coal mine (east mine) (***C***)	$1,268,120	$1,407,381	$1,713,755	$1,431,839	$1,595,658	$1,956,060
Spring Creek Coal Mine (***C***)	$31,693	$35,040	$42,401	$35,627	$39,563	$48,223
Stillwater Mining Company-1 (***M***)	$1,341,870	$1,489,230	$1,813,422	$1,515,111	$1,688,457	$2,069,819
Stillwater Mining Company-2 (***M***)	$1,026,867	$1,135,282	$1,373,793	$1,154,322	$1,281,855	$1,562,426
Beaverhead Talc Mine (***Mfg***)	$221,487	$245,198	$297,362	$249,362	$277,254	$338,617
Exxon Mobile Refinery (***R***)	$12,526,340	$13,867,313	$16,817,454	$14,102,828	$15,680,274	$19,150,656
Montana Tunnels Mining (***M***)	NA	NA	NA	NA	NA	NA
Luzenac-Yellowstone talc mine (***Mfg***)	NA	NA	NA	NA	NA	NA
Bull Mountain Coal Mine (***C***)	$570,482	$630,712	$763,218	$641,290	$712,142	$868,014
Barretts Mineral (***Mfg***)	$2,498,711	$2,762,519	$3,342,896	$2,808,851	$3,119,180	$3,801,903
Montana Aviation Research (***Oth***)	$79,234	$87,599	$106,003	$89,068	$98,909	$120,558
M & W Milling & Refining (***Mfg***)	$46,143	$51,083	$61,950	$51,950	$57,761	$70,545
Asarco/Mike Horse mine water treatment (***M***)	$99,977	$110,680	$134,226	$112,559	$125,150	$152,848
Columbia Falls Aluminum Co (***Mfg***)	$952,237	$1,052,772	$1,273,949	$1,070,429	$1,188,693	$1,448,873
Asarco Inc. (***Mfg***)	$217,091	$240,010	$290,434	$244,036	$270,998	$330,313
YELP electric generation (***E***)	$395,217	$436,943	$528,741	$444,272	$493,356	$601,341
Montanore Mine (***M***)	$11,475	$12,714	$15,441	$12,932	$14,390	$17,597
REC Advanced Silicon (***Mfg***)	$1,825,542	$2,018,278	$2,442,298	$2,052,129	$2,278,853	$2,777,646
M&K Oil Co-waste disposal (***OG***)	$26,622	$29,433	$35,617	$29,927	$33,233	$40,507
Sleeping Buffalo Hot Springs (***Oth***)	$27,558	$30,508	$36,998	$31,026	$34,496	$42,131
Pinnacle Gas Resources (***OG***)	NA	NA	NA	NA	NA	NA
Barretts-Regal Talc Mine (***Mfg***)	$228,193	$252,285	$305,287	$256,516	$284,857	$347,206
Fidelity Oil and Gas (***OG***)	$3,476,643	$3,858,437	$4,698,384	$3,925,492	$4,374,613	$5,362,681
Headwaters Livestock Auction (***Oth***)	CAFO					
Wolf Mountain Coal (***C***)	$10,254	$11,352	$13,767	$11,545	$12,836	$15,677

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Table 5-Estimated Average Annual Costs (Capital and O&M Cost) for Affected Montana Businesses
(***Sector Codes: M-metal mining, C-Coal Mining, OG-Oil and Gas, E-Electric Generation, R-Refineries, Mfg-General Manufacturing, Oth-Other***)

Company (Sector code)	Original	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Cattle Development Center (***Oth***)	CAFO					
James Guercio-OW ranch (***OG***)	$270,722	$300,452	$365,858	$305,674	$340,646	$417,586
IOFINA Natural Gas Water Treatment Facility (***OG***)	NA	NA	NA	NA	NA	NA
Total	**$364,205,474**	**$402,798,363**	**$487,702,718**	**$409,576,430**	**$454,974,963**	**$554,851,734**

SIGNIFICANT IMPACT ANALYSIS[4]

IMPACTS ON BUSINESSES AND MONTANA AS A WHOLE

Because of the technical challenges and high costs of meeting the nutrient standards with today's technologies (especially TN), Montana believes that some firms in the state having to meet the base numeric nutrient standards will have to shut down or cut back their operations, or have to determine if affordable 'non-discharge' options are available. Non-discharge options include, for example, a. land application, b. total/seasonal retention , c. piping water long distances away from state waters, and d. trading. These non-discharge options, including land application, could be very expensive and are often not feasible in certain areas (such as places far from open land or with few trade partners) or during the cold times of the year. Some of the 51 affected businesses would simply not have a non-discharge option available, and some non-discharge options may be as expensive as discharge options.

Montana believes that there will also be an adverse effect from having to meet base nutrient criteria on new businesses starting up in Montana. Small businesses, with generally thinner margins, will especially be affected because they will most likely not be able to afford RO or non-discharge options.

In the Billings areas, companies discharging into the Yellowstone River would likely have to meet, end of pipe, criteria comparable to the 'wadeable streams' standards of Western Montana (i.e., about 0.03 mg TP/L and 0.3 mg TN/L). Treating to criteria at the end of pipe would be extremely costly to businesses in Billings, including refineries. These businesses might have to shut down, or might choose to relocate due to high treatment costs. Montana's refineries provide almost all of Montana's liquid petroleum products (as well as about 50% of Spokane's and 30% of North Dakota's). Shutting down two or all three refineries in the Billings areas would be very damaging to Montana in terms of petroleum products supply shortages, although Montana does produce more refined product than it consumes. In addition, the Stillwater mine is one of the only sources of palladium and platinum in North America, and a shutdown would choke off that supply. Clearly, these four businesses are crucial to the larger overall economy in the state, and shutting them down (or even scaling back) would have significant and widespread effects within and outside of Montana.

One way to look at the 'significant impact' on businesses is to see what the impacts would be on the largest affected businesses in Montana. If the largest businesses are significantly impacted, then it is very likely that smaller businesses will also be impacted significantly due to the 'economies of scale' advantage of larger businesses and their deeper pockets of available financial resources.

[4] Note: Much of the data in this section came from the U.S. Census Bureau, 2007 Economic Census, 2007 Economic Census of Island Areas, and 2007 Nonemployer Statistics (U.S. Census Bureau, 2007). These files are released on a flow basis from March 2009 through mid-2011. The national data are subject to change; they will be replaced when updated data are added from the Geographic Area Series and Summary Series.

Some businesses that would not have to shut down as a result of having to meet base standards, may have to scale back production, and/or lay off workers. An example of this is Fidelity Exploration & Production Company who is currently engaged in developing and extracting coal bed methane natural gas from subsurface formations in the Powder River Basin. As indicated in a recent DEQ economic analysis, as a result of the new water quality sodium standards under TBELs (Technology-Based Effluent Limits), Fidelity would have to cut back temporarily or permanently some current and future natural gas production resulting in lower revenues/profits, less jobs being created, and fewer tax and royalty payments to the State of Montana. These estimated effects include production taxes paid to Montana down by almost $13 million from 2011-2015, federal royalties down by almost $9 million (half of which goes to Montana), state royalties down by just over $1 million, and fee royalties down by almost $16 million to private land owners. Also, up to 735 million cubic feet (MCF) of lost production of natural gas would occur due to shutting in some wells (Montana Department Environmental Quality, 2010). Another estimated $5.4 million in additional annual costs for Fidelity (as estimated in **Table 1**) to meet nutrient criteria would result in even further cutbacks.

The main affected business sectors in Montana, as defined on page 4, would be significantly affected. The oil and gas industry as a whole in Montana has revenues of about $1.3 billion annually (U.S. Census Bureau, 2007). The annual cost of meeting nutrient criteria would be about $4 to $6 million annually or about 0.3% to 0.5% of annual revenue. The percentage of actual profits (revenues minus costs) would be higher, as it would be for all major sectors.

Metals mines in Montana as a whole would have to pay an estimated $9.7 to $14.9 million annually in estimated costs to meet base numeric criteria which is 0.9% to 1.3% of total annual revenue in Montana for that sector which is about $1.11 billion. (U.S. Census Bureau, 2007). In addition, metal mines prices and thus revenues fluctuate a lot and present a further challenge to additional costs.

Coal mines in Montana as a whole would have to pay $11.5 to $17.5 million annually in estimated costs to meet base numeric criteria which is 2.4 to 3.7% of total annual revenue for that sector (U.S. Census Bureau, 2007). In addition, the mine-mouth price of coal in Montana (in 2007 dollars) has been cut in half since the early 1980s and shows no signs of rising in the coming years (Montana Department of Environmental Quality, 2012).

DEQ estimates that each of the three large refineries in Montana would require annual investments of between $4.6 and $19.2 million per year to comply with the nutrient criteria (see **Table 5** above), and about $28.6-$43.8 million for all three. Based on information from the U.S. Census Bureau, the annual revenue for that sector is $5.45 billion. This indicates that the annual costs to meet nutrient criteria are between 0.5% and 0.8% of total revenue for the refinery sector. In addition, refineries will be hit with substantial new air quality regulations from EPA in 2012 (e.g. mercury standards) that will cost additional money.

An additional alternate analysis was performed for refineries in the Billings area. These refineries as a whole had an annual input of 60 million barrels of crude from 2004-2007. Based on the financial reports for one of the major oil companies in the US, earnings (which is revenues minus costs) from US-based refining for five fiscal quarters (the fourth quarter of 2009 and all four quarters of 2010) have fluctuated between ($1.80) and $2.68 per barrel (Exxon Mobil Corporation, 2011). This provides estimated earnings for each of the Billings-area refineries between ($36) million and $53.6 million per year (assuming about 20 million barrels of crude input to each annually), making the annual investments of between $4.6 and $19.2 a significant portion of their earnings or an exacerbation of their losses (between 9% and 36% of earnings in the best-case estimated scenario of $53.6 million in earnings per refinery, and a much greater share for any earnings less than that). In some fiscal quarters, refineries appear to be losing money, making such costs harder to bear.

The electric power generation, transmission and distribution sector in Montana in 2007 employed 2,348 total workers (U.S. Census Bureau, 2007). Annual costs for the three affected generating plants would be an estimated $418.7 million (see **Table 1** above). The total electricity retail sales for Montana in 2010 were $921 million (U.S. Energy Information Administration, 2011). Thus, estimated annual costs of complying with nutrient criteria would be 29.8 to 45.5% of total annual revenues for this sector. (Note: For electric generation, DEQ took the overall sector labeled “Electric power generation, transmission and distribution” (NAICS 2211) and subtracted the information for “Electric Power Distribution” (NAICS subsector 221122) to isolate ‘Electric generation” as much as possible. The data in this file come from separate 2007 Economic Census Industry Series, Geographic Area Series, and Summary Series data files, as well as data files from the 2007 Economic Census of Island Areas and the 2007 Non-employer Statistics.(U.S. Census Bureau, 2007)

Further, if electricity costs were all passed on to consumers (we actually assumed otherwise), this would translate to more than $30 each month in an electric bill increase for every resident in Montana. The Corette generation plant of 153 Megawatts (MW) capacity has an estimated cost of $316 million per year to meet criteria (due to a large effluent flow) and is a baseload generation plant for PPL Montana for its electricity customers. It would likely close with such high costs, causing PPL to lose a significant portion of its electricity supply portfolio, and causing electricity customers in Montana to have to get a portion of their electricity supply elsewhere.

The Sugar and confectionery product manufacturing sector in Montana in 2007 had payroll costs of $13.3 million and undetermined revenues (U.S. Census Bureau, 2007). Annual costs to meet base numeric criteria are estimated $34.8 million annually or almost three times the payroll costs. Sidney Sugars in Sidney, one of the two sugar plants affected, is a major employer in Richland County providing full time employment for approximately 150 people and part time employment for 280 more with an annual payroll of approximately $5.7 million. Another $50 million is paid out to local farm families for sugar beets grown on 47,500 acres of irrigated land. The refinery also ships 200,000 tons of sugar, pulp and molasses by rail and 75,000 tons by truck (Sidney Area Chamber of Commerce and Agriculture, 2012). Sugar refineries often break even in their operation and accept a sugar price set by a ‘price floor’, leaving a very slim operating margin for nutrient treatment costs that would be over $30 million annually.

For manufacturing in Montana overall, the nutrient criteria would affect a small number of businesses in Montana out of the total number that are in that sector. The estimated annual costs to those affected businesses would be $35 to $54 million, versus $10.6 billion in Montana for all of manufacturing in Montana.

Smaller businesses such as small manufacturers and family-run businesses would almost certainly not be able to afford advanced biological treatment, much less RO. The larger businesses with small costs due to small effluent flows, such as the coal mines, would almost certainly look for alternate ways of disposing their water. The impact to those businesses would depend upon the costs of something like land application.

It is important to note in considering the numbers above that the total revenues listed cover the entire sector in Montana, whereas only some businesses in these sectors are affected. For example, only a small portion of the entire “General Manufacturing” sector would be affected by the nutrient criteria, but DEQ only found revenue numbers for the entire sector. Thus, affected businesses in that category would be impacted more than the sector numbers indicate.

Adding up the sectors, total cost would be $364 to $555 million annually out of a total revenue of $19.9 billion or about 1.8% to 2.8% of total revenue. While some sectors annual costs would be less than 1% of total revenue, all of the costs of these six main sectors together would probably be greater than 2% of total annual revenues each year. Thus, these costs are likely to be significant to Montana’s affect businesses sectors and thus to Montana business overall.

CASE STUDIES

Stillwater[5]

The Stillwater Mining Company (SMC) operates two underground mines and processing facilities in south-central Montana and is one of the largest private employers in Montana (over 1000 employees). SMC is the only primary producer of palladium and platinum in the United States with the majority of the metal production from the mines utilized in clean air technologies and catalytic converters for the auto industry. SMC's multiple stage water management and water treatment facilities are engineered for treatment of nitrogen species that occur in mine waters due to the use of blasting agents in underground mining operations. Ammonium nitrate (the same compound used in agricultural fertilizer) is the primary component of the explosives used for mining.

The following is a brief outline of SMC's water treatment/management system components:

a. Primary Treatment : Clarification (removal of suspended solids)
b. Secondary Treatment: Biological denitrification (fixed bed and moving bed bioreactors)
c. Enhanced Secondary Treatment : Biological nitrification + denitrification (moving bed bioreactors)
d. Tertiary water management/treatment: recycle/reuse (mine support) and recycle/reuse for land application (Agronomic uptake - Stillwater Mine Hertzler facility)
e. Backup treatment system: Reverse osmosis (low volume unit to be used in short-term situations where primary and secondary treatment sustain an unplanned upset)

SMC's most recent study on nitrogen treatment technologies was conducted in 2004 in order to identify the Best Available Technology for treatment of ammonia. The study looked at biological treatment, reverse osmosis, ion exchange, breakpoint chlorination, and ammonia stripping. The study concluded that enhanced biological nutrient removal was the best available technology for the water management systems at SMC and that the treatment efficiency was equal to or better than the other technologies. Additionally, the study found that the treatment technology (true nutrient removal, not just separation/filtration of nitrogen compounds) was superior to the other treatment technologies due to the lack of waste stream and lower energy consumption and operating cost.

Biological treatment of nutrients does, however, come with limitations and challenges. Consistency in treatment efficiency is one of the primary challenges. The nitrifying and denitrifying bacteria are sensitive to changes in water temperature and chemistry as slight changes in temp or pH can cause sharp fluctuations in bacteria vitality and treatment efficiency. Likewise a sudden increase in flows or sustained increases over time can cause reduced contact and retention time resulting in decreased efficiencies.

Biological treatment of nitrogen (primary, secondary, and enhanced secondary) at the SMC facilities results in Total Nitrogen (TN) effluent concentrations that average 4-5 mg/L TN during the past 3 years. During that same time frame, the range of effluent concentrations at the SMC treatment systems is 1 mg/L to 15 mg/ l (does not include upset conditions). Consistency of treatment efficiency is easier to maintain during the summer time when water temperatures are warmer and water chemistry is more consistent. (It should be noted that base numeric nutrient standards will only apply in summer in most cases.) During the summer, the SMC nutrient treatment systems are able to consistently achieve 5 mg/L, however, during the winter months (6 months of the year), colder temperatures and higher TDS in the mine waters can trigger periods of variability in treatment efficiency that can result in effluent concentrations of up to 15 mg/L. Because of this variability, it is difficult to numerically quantify the limits of technology (with less than 5 mg/L accuracy) for enhanced biological nutrient treatment such as we experience in the mountainous headwaters areas across Montana.

[5] (Gilbert, Bruce, personal communication 2011)

Table 6. General Summary of Treatment Efficiency for total nitrogen (TN) as well as representative effluent TN concentrations

Nitrogen Removal Performance	Stillwater Mine	East Boulder Mine
Effluent TN* (99% confidence interval**)	10 mg/L	10 mg/L
Effluent TN (5-yr avg)	6 mg/L	10 mg/L
Effluent TN (3-yr avg) (w/EBNR***)	5 mg/L	4 mg/L
Effluent TN (3-yr effluent range)	1 mg/L – 15 mg/L	1 mg/L – 15 mg/L
Effluent TN (3-yr avg)	32 mg/L	39 mg/L
Nitrogen Removal Efficiency (3-yr)	85%	90%

*TN = Total Nitrogen (Nitrate + Nitrite + Ammonia + Organic N)
** 99% confidence interval means that (on average) the effluent is less than or equal to 10 mg/L 99% of the time, or the effluent exceeds 10 mg/L approx. once every 100 days
*** Enhances Biological Nutrient Reduction is a systems upgrade that includes mixed-bed bioreactors for nitrification (ammonia reduction) and denitrification (nitrate reduction)

Below is a summary of capital expenditures for water treatment systems at each of the mine sites. The capital expenditures represent the time period of 1995 to 2011.

Table 7. Capital expenditures for water treatment systems at each of the mine sites

Water Treatment	Stillwater Mine	East Boulder Mine	Total
Capital Cost (1995-2011)	$7,500,000	$3,800,000	$11,300,000

In addition to capital expenditures, operating and maintenance costs for the SMC water treatment systems can range between $350K and $500K per year per site depending on flow rates, maintenance requirements (including labor), and mechanical replacements. Additionally, it should be noted that treatment capacity is more sensitive to flow than concentration which adds potential to inflate both capital and operating costs dramatically even if overall influent concentrations are relatively low. Mine size, hydraulic setting, changing hydraulic conditions, production rate and commodity pricing (to name a few) can impact significantly on capital requirements to sustain and grow the company and meet changing regulatory mandates. Complicating the picture further is the fact that current operational costs and future cost projections are influenced by more site-specific parameters (flow, temperature, ph, TDS, contact time, bacterial regime etc.) that are ever-changing. In order to meet these operating challenges and maintain operational flexibility, biological treatment design normally requires process redundancies and additional capacity to compensate for upset conditions and assure a reasonable availability in order to meet treatment design criteria. These factors all impact upon the ability of new and existing mines to meet the new, low surface water standards and add an additional complexity to the economic decision-making process inherent to mine development. Likewise, the variability and cyclic nature of commodity prices can significantly impact on a Company's ability to meet new or increased capital budget allocations associated with new regulatory standards.

The proposed removal targets (Montana's nutrient criteria) would require nitrogen removal rates of over 99% which are at least an order of magnitude lower than can be achieve with the current Best Available Technology, according to SMC.

Annualizing the above costs (existing, current treatment costs) would come to $1.8 million ($1.06 million capital annualized plus $350,000-$500,000 annual operating costs at each site). This is in addition to an estimated $3.6 million annually to get to base nutrient criteria or about $5.4 million per year total in annual costs for nutrient treatment. Is $3.6 million in additional annual cost significant and widespread? Here are Stillwater's (Stillwater Mining Company, 2011) earnings before taxes:

- 2010 $50.4 million
- 2009 -$8.7 million
- 2008 -115.8 million

Palladium and platinum prices reached high levels in 2010 from very low levels in 2008. In the best year, the annual additional cost of nutrient treatment beyond current treatment is 7% of profits. In the worst years, the company does not make a profit. Stillwater is experiencing great uncertainty in commodity prices and would probably not invest a lot of additional money for treatment beyond what it has already done. Palladium and Platinum prices as of December, 2011 are down about 20-30% from 2010 levels (KITCO, 2012).

Smurfit Stone

When they were still in operation in 2009, Smurfit-Stone stated that they could not afford advanced mechanical or biological treatment. They estimated that advanced mechanical treatment would have cost on the order of $53 million in capital costs, and the mill would have closed faced with this level of treatment costs (Caprara, 2009). The mill closed down anyway in 2010 (due to economic influences unrelated to nutrient water-quality criteria), so this is only a cost example.

Refineries[6]

Using Best Available Demonstrated Technology

TN: The current average release of TN in the water effluent of Billings area refineries is >5 TN mg/L. The maximum is 12-55 TN mg/L. From primary treatment to discharge the steps for best available technology (BAT) are: primary treatment to aeration tank to anoxic denitrification to final aerobic treatment to clarifier to filter to discharge. A supplemental carbon source is added between the aeration tank and the anoxic denitrification. For a 60,000 barrels per day (BPD) refinery already nitrifying, the approximate capital cost of adding the anoxic denitrification, final aerobic treatment, and a filter is $5 million.

TP: The typical average effluent concentration of TP in the Billings area refineries is 0.08 mg/L to 0.14 mg/L; 95th percentile effluent total phosphorus = 0.2 mg/L to 0.7 mg/L. From Biological WWTP to discharge the steps for BAT are: add alum, ferric chloride or lime to chemical precipitation (clarifiers) to discharge. Sludge is removed from the chemical precipitation step for dewatering and disposal. For 60,000 bpd refinery, approximate capital cost is $6 million, and sludge generation is approximately 80 tons/year.

According to Dr. Matt Gerhardt of Brown and Caldwell (engineering consultants), limits of treatment technology for nitrogen at the refineries is:

- ~3 mg/L as N average
- >10 mg/L as N maximum

The limits of technology for phosphorus removal are:

- 0.07 mg/L as P average
- 0.2 – 0.7 mg/L as P maximum

These costs are lower than the estimated costs to meet nutrient criteria) because this technology would only meet BAT (~WERF Level 3) and not base numeric criteria.

WIDESPREAD ANALYSIS

The final step in the S&W demonstration for Montana businesses is the widespread test. USEPA guidance (U.S. Environmental Protection Agency, 1995) allows flexibility to go beyond direct ratios or specific tests for a Widespread finding, and suggests a list of “essay style” questions to use. From the EPA guidance:

[6] (Gerhardt, 2009)

> "The financial impacts of undertaking pollution controls could potentially cause far-reaching and serious socioeconomic impacts. If the financial tests outlined in Chapter 2 and 3 suggest that a discharger (public or private) or group of dischargers will have difficulty paying for pollution controls, then an additional analysis must be performed to demonstrate that there will be widespread adverse impacts on the community or surrounding area. There are no economic ratios per se that evaluate socioeconomic impacts. Instead, the relative magnitudes of indicators such as increases in unemployment, losses to the local economy, changes in household income, decreases in tax revenues, indirect effects on other businesses, and increases in sewer fees for remaining private entities should be taken into account when deciding whether impacts could be considered widespread. Since EPA does not have standardized tests and benchmarks with which to measure these impacts, the following guidance is provided as an example of the types of information that should be considered when reviewing impacts on the surrounding community." (U.S. Environmental Protection, 2012).

DEQ considered the widespread analysis based on the following basic question: For Montana, what are the economic and social ripple effects of the substantial impacts to businesses on the local area where the business is located and on the state as a whole? Other questions included the following: If some small and medium sized businesses shut down, what is the impact? What is the impact of lower tax revenue to Montana in a time of lower revenue due to the Recession? What would be effects of royalty loss from less oil and gas production due to nutrient standards?

An important step in these questions was to define the geographic area where project costs pass through to the local economy. For Montana's widespread analysis, DEQ established the entire state as the "geographic area" considered in the widespread demonstration.

Another important aspect of Widespread impacts is to look at the effects of the current Recession on Montana's businesses.

MONTANA MANUFACTURING DEFINED

Manufacturing Defined

Montana's manufacturing, energy and mining sectors would be hit the hardest by having to meet nutrient criteria due to the number of businesses affected in those sectors. Compared with the U.S. state average, Montana has less manufacturing as a percentage of the whole economy according to the University of Montana Bureau of Business and Economic Research (BBER)(Bureau of Business and Economic Research, 2012). Unlike manufacturing, however, mining clearly has a higher percentage of workers in Montana than the U.S. average. About 2% of employment in Montana is located in the Mining industry, while only about 0.6% of U.S. employment is in Mining (Montana Department of Labor & Industry, 2011). As mentioned earlier, Stillwater is the only primary source of palladium and platinum in North America, with approx. 1300 employees.

Despite a lower than average share of the U.S. economy, the state's manufacturers as defined by the Montana Bureau of Business and Economic Research (BBER) employed 21,000 workers in 2010, producing more than $1 billion in labor income, and $10 billion in total sales (Morgan, et al., 2011). As of September 2011, the Natural Resource and Mining industry accounted for 8,200 jobs. Together, this was just over 5% of all 436,000 non-agricultural jobs in Montana (Montana Department of Labor & Industry, 2011). The U.S. Bureau of Economics states that in 2010, out of $36.1 billion in total Montana gross domestic product (GDP), that $1.8 billion was from Mining and Oil and Gas, and that $1.8 billion was from Manufacturing (U.S. Department of Commerce, 2012). Taken together, that is about 10% of Montana's GDP in 2010, although it is important to note that only some of the businesses in those two sectors would have to meet nutrient criteria.

Montana GDP--Bureau of Economics Regional Analysis (millions of current dollars) (U.S. Department of Commerce, 2012).

	2009	2010
Mining	1,593	1,838
Oil and gas extraction	304	(NA)
Montana Mining (except oil and gas)	997	(NA)
Montana Support activities for mining	291	(NA)
Nonmetallic mineral product manufacturing		62
Montana industry total	34,999	36,067

Recession concerns

Montana's industries, as in the rest of the U.S., are suffering from the recession. During the current recession, Montana's Construction, Manufacturing, and Trade, Transportation, and Utilities industries were the hardest hit sectors. Job losses in these industries had a larger impact in some regions than others. The Northwest region of Montana was highly concentrated in Manufacturing in 2007, and was impacted by the losses in the industry. Declines in manufacturing since 2001 were largest in Montana's wood and paper products industry with segments of Montana's metals, machinery, and nonmetallic minerals manufacturers also suffering declines (Montana Department of Labor & Industry, 2011).

More than 60 percent of responding firms to BBER's annual manufacturers survey (Jan 2010) indicated the recession has caused their firm to fundamentally change the way they plan to operate in the future. Most of the major changes involved reducing costs and operating more efficiently. Other major changes included diversification into new products and markets, or focusing on key products and projects. The survey results indicate the widespread impacts in 2009, with over 60 percent of responding Montana manufacturers reporting decreased production and sales. Sixty-five percent of surveyed Montana manufacturing firms reported decreased profits, with only 17 percent indicating profits equal to 2008. The proportion of respondents that reported curtailments of production increased to 49 percent, up from 37 percent in 2008. Seventeen percent permanently eliminated production capacity in 2009 versus 9 percent in 2008. The number of workers in 2009 relative to 2008 declined at 50 percent of the respondent facilities while 10 percent showed an employment increase (Bureau of Business and Economic Research, University of Montana, 2010).

During the recession, payroll employment in Montana declined 4.8%, leaving a large number of Montana workers unemployed. Manufacturing lost 4,040 jobs from 2007-2010, and natural resources and mining, 760 jobs. Job growth exiting the recession is expected to be slower than before the recession, with employment growth from 2010 to 2020 expected to average 0.9% annually compared to 1.2% per year from 2000 to 2007. At this pace, it will take at least four to five years to regain the jobs lost in recent years unless economic recovery picks up. Because of slow job growth, combined with the large number of existing unemployed workers plus the younger workers joining the labor force for the first time, the unemployment rate in Montana is expected to remain at higher levels for several years. Manufacturing would gain pre-Recession jobs lost not until after 2020 according to the Montana Department of Labor and Industry (Wagner, 2011).

The Production, Transportation and Material Moving, and Construction and Extraction occupational groups are also not expected to return to the 2007 employment peak before 2020. These occupational groups likely will continue to have excess labor throughout the next decade. In Montana, about 23,000 jobs requiring only on-the-job training or work experience were lost. It will take many years to re-employ these workers, even though about 3,000 new lower-skill jobs are expected to be added each year. In comparison, jobs requiring some type of post-high school education, almost none of which would be affected by having to meet nutrient criteria, did not show overall losses. The roughly 1,000 jobs in this category added annually will need to be filled by newly trained workers (Wagner, 2011).

In sum, Montana's manufacturing, mining and energy production sectors are the areas most affected by nutrients standards and their associated costs. They are also among the areas that were hit hardest during the recession, and could have special challenges taking on significantly more costs.

WIDESPREAD CONCLUSIONS

- The Recession is making the economics of businesses and their workers more challenging that during non-recession periods. The very high costs of meeting base numeric criteria would deepen these challenges.
- Montana was 41st in the nation in per capita income as of 2009 at $22,881 (U.S. Census Bureau, 2012). Prices in Montana are about average for the U.S. across all goods, with housing slightly cheaper and certain types of goods (e.g. fresh foods) slightly more expensive due to geographical remoteness. Montanans on average do not have as much disposable income as the average American, and may have slightly higher living expenses due to long travel distances and higher heating bills. Losses in income from affect businesses could especially impact Montanans.
- As noted above, some affected businesses are located in or near small towns. Since most small towns do not have diverse economies, even a small decrease in business and in population can have a large effect on them. For example, some small Montana towns have less than 10 businesses total.
- To the extent that gas and oil wells shut down due to meeting base numeric nutrient criteria, royalty payments to landowners (those who own their mineral rights) would decrease. Reduced royalty money as a result of reduced oil and gas production and mining production would lessen supplemental income to mostly rural landowners (including members of Reservations) who now collect that money. Royalty payment losses could include those to private landowners, the state of Montana and the Tribes.
- To meet the base numeric nutrient criteria will require hiring highly qualified wastewater engineers for each affected business. There could be widespread impacts associated with finding these qualified staff for facilities across the state and then paying them a competitive salary. Such operators may be hard to find for Montana businesses.
- Some businesses may not choose to locate in Montana if Montana were to require compliance with stringent criteria immediately, while other states do not. Eventually, all U.S. states will have to meet nutrient criteria, so this effect will probably decline over time.
- If electricity costs from meeting nutrient criteria were passed on to consumers, the average electricity bill per person in Montana would go up $30 per month (averaged over all Montana citizens). More likely, the affected generation plants would simply close down such as Corrette.
- The 2010 census data showed that Montana's population is aging, with many on fixed incomes. This trend, coupled with any increased living expenses associated with meeting the base nutrient standards, could have negative impacts on a statewide scale.
- All states including Montana can use every dollar of tax money collected during the Recession and resulting time of state deficits. Any reduction in tax money collected from decreased business activity would hurt state coffers. Montana's budget is only one or two or three states to remain positive (budget surplus) due in part to natural resource taxes.
- DEQ's substantial and widespread analysis is based on the assumption that reverse osmosis or some ion exchange treatment technology would be required. Either technology is both economically and environmentally costly. Reverse osmosis generates brine that must be disposed of properly and results in significantly higher greenhouse gas emissions, electricity and chemical usage. Aggregated at the statewide scale, both the economic and environmental implications of meeting Montana's criteria would have widespread impacts for the State of Montana, including finding faraway places to dispose of the RO brine.
- Closure of two or three of the three major refineries in the Billings area could result in petroleum product shortages for Montana and nearby states.
- Most of the businesses affected pay higher wages than the Montana average. Any loss in these jobs would thus have a greater effect.

CONCLUSION

It is DEQ's best professional judgment that the resulting costs of complying with the base numeric nutrient criteria immediately would result in substantial costs beyond what individual firms can internalize. This would result in some businesses closing and a scaling down in economic activity in particular economic sectors of Montana. Energy production (electricity and fossil fuel), metals mining and manufacturing would be hit the hardest. At this point in time, using reverse osmosis on 100% of effluent flow is simply too expensive for businesses to operate, and comes with a host of technical problems given Montana's winters and the business operations of affected companies (such as highly variable water flows at certain mines). The cumulative impact on these individual firms will create a widespread economic negative effect that will exacerbate Montana's current economic situation within the general U.S. recession. Aside from widespread impacts such as potential businesses and jobs lost, electricity prices and supply along with refined petroleum products could be greatly impacted if certain Billings plants had to scale back or close down.

Adding up the affect industry sectors in Montana, total cost would be $364 to $555 million annually out of a total revenue in those sectors of $19.9 billion, or about 1.8% to 2.8% of total revenue. While some sectors annual costs to meet nutrient criteria would be less than 1% of total revenue, all of the costs of these six main sectors together would probably be greater than 2% of total annual revenues each year. Thus, these costs are likely significant to Montana's affect businesses sectors and thus to Montana business overall. Impacts on Montana's tax revenues, rural citizens, energy usage in water treatment, royalty payments, and business climate would probably be widespread as a result of existing and new businesses having to meet the strict nutrient criteria.

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APPENDIX A—COST WORKSHEETS

Table A-1. Base Criteria Calculations 5%

NPDES ID	Facility Name	Flow (mgd)	Current Level of Nutrient Treatment	Required Level of Nutrient Treatment under the Criteria	Capital Cost per MGD ($million /MGD)	Facility Upgrade Capital Costs ($million)	Annualized Capital Costs (Assumed 20 years, 5% rate; $million/year)	Annualized Capital Costs (Assumed 20 years, 5% rate; $/year)	Operations ($1/ MG/day Treated)	Operations Costs ($/ year/ 1 MGD)	Facility Upgrade Operations Costs (annual) based on Facility MGD	Membrane Replacement Cost ($24,000 /yr/1 MGD)*Actual Flow	Total Operations costs including membrane replacement	Total Operations costs including membrane replacement + Labor Low (15%)	Total Operations costs including membrane replacement + Labor Hi (48%)
MT0000264	CENEX HARVEST STATES COOP.	***2.174***	***Level 1***	**100% RO**	19	$41.31	$3.31	$3,314,500	1610	587,650	1,277,551	52,176	1,329,727	1,826,902	2,920,687
MT0000256	CONOCOPHILLIPS - BILLINGS REFINERY	***2.66***	***Level 1***	**100% RO**	19	$50.54	$4.06	$4,055,460	1610	587,650	1,563,149	63,840	1,626,989	2,235,308	3,573,610
MT0000191	MONTANA RESOURCES	***5.04***	***Level 4***	**100% RO**	13	$65.52	$5.26	$5,257,494	980	357,700	1,802,808	120,960	1,923,768	2,712,392	4,447,365
MT0000248	SIDNEY SUGARS INCORPORATED	***1.3***	***Level 1***	**100% RO**	19	$24.70	$1.98	$1,981,992	1610	587,650	763,945	31,200	795,145	1,092,444	1,746,501
MT0000281	WESTERN SUGAR COOPERATIVE	***9.36***	***Level 1***	**100% RO**	19	$177.84	$14.27	$14,270,342	1610	587,650	5,500,404	224,640	5,725,044	7,865,595	12,574,808
MT0000477	EXXONMOBIL REFINING & SUPPLY	***2.7***	***Level 1***	**100% RO**	19	$51.30	$4.12	$4,116,445	1610	587,650	1,586,655	64,800	1,651,455	2,268,922	3,627,348
MT0000485	TRIDENT PLANT	***0.0072***	***Level 2***	**100% RO**	15.6	$0.11	$0.01	$9,013	1510	551,150	3,968	173	4,141	5,493	8,467
MT0000892	DECKER COAL CO (WEST MINE)	***1.12***	***Level 4***	**100% RO**	13	$14.56	$1.17	$1,168,332	980	357,700	400,624	26,880	427,504	602,754	988,303
MT0020460	YELLOWSTONE BOYS & GIRLS RANCH	***0.02***	***Level 1***	**100% RO**	19	$0.38	$0.03	$30,492	1610	587,650	11,753	480	12,233	16,807	26,869
MT0021431	MT BEHAVIORAL HEALTH INC WWTP	***0.1***	***Level 1***	**100% RO**	19	$1.90	$0.15	$152,461	1610	587,650	58,765	2,400	61,165	84,034	134,346
MT0023566	ELKHORN HEALTH CARE WWTP	***0.015***	***Level 1***	**100% RO**	19	$0.29	$0.02	$22,869	1610	587,650	8,815	360	9,175	12,605	20,152
MT0023639	BOULDER HOT SPRINGS WWTP	***0.085***	***Level 3***	**100% RO**	13.9	$1.18	$0.09	$94,807	1220	445,300	37,851	2,040	39,891	54,111	85,398
MT0024210	DECKER COAL CO (EAST MINE)	***0.89***	***Level 4***	**100% RO**	13	$11.57	$0.93	$928,407	980	357,700	318,353	21,360	339,713	478,974	785,348
MT0024716	STILLWATER MINING COMPANY	***0.94176***	***Level 4***	**100% RO**	13	$12.24	$0.98	$982,400	980	357,700	336,868	22,602	359,470	506,830	831,022
MT0026808	STILLWATER MINING COMPANY	***0.648***	***Level 3***	**100% RO**	13.9	$9.01	$0.72	$722,761	1220	445,300	288,554	15,552	304,106	412,521	651,032
MT0027821	BEAVERHEAD TALC MINE	***0.10368***	***Level 1***	**100% RO**	19	$1.97	$0.16	$158,071	1610	587,650	60,928	2,488	63,416	87,127	139,290
MT0028321	EXXON MOBIL BILLINGS REFINERY	***5.86368***	***Level 1***	**100% RO**	19	$111.41	$8.94	$8,939,820	1610	587,650	3,445,792	140,728	3,586,520	4,927,493	7,877,634
MT0028428	MONTANA TUNNELS MINING INC	***0***	***Level 5***	**100% RO**	6.5	$0.00	$0.00	$0	490	178,850	0	0	0	0	0
MT0028584	LUZENAC AMERICA INC - YELLOWSTONE MINE	***0***	***Level 3***	**100% RO**	13.9	$0.00	$0.00	$0	1220	445,300	0	0	0	0	0
MT0029891	BARRETTS MINERALS INC	***1.5768***	***Level 3***	**100% RO**	13.9	$21.92	$1.76	$1,758,719	1220	445,300	702,149	37,843	739,992	1,003,800	1,584,177
MT0030015	M & W MILLING & REFINING INC	***0.0216***	***Level 1***	**100% RO**	19	$0.41	$0.03	$32,932	1610	587,650	12,693	518	13,212	18,151	29,019
MT0030031	ASARCO LLC - MIKE HORSE/ANACONDA MINE WATER TREATMENT SYSTEM	***0.0468***	***Level 1***	**100% RO**	19	$0.89	$0.07	$71,352	1610	587,650	27,502	1,123	28,625	39,328	62,874
MT0030147	ASARCO INC	***0.136994***	***Level 3***	**100% RO**	13.9	$1.90	$0.15	$152,799	1220	445,300	61,003	3,288	64,291	87,211	137,635
MT0030180	YELLOWSTONE ENERGY LIMITED PARTNERSHIP FACILITY	***0.2494***	***Level 3***	**100% RO**	13.9	$3.47	$0.28	$278,174	1220	445,300	111,058	5,986	117,043	158,769	250,567
MT0030279	MONTANORE MINERALS CORP MONTANORE MINE	***0.01584***	***Level 5***	**100% RO**	6.5	$0.10	$0.01	$8,262	490	178,850	2,833	380	3,213	4,452	7,179
MT0030350	REC ADVANCED SILICON MATERIALS LLC	***1.152***	***Level 3***	**100% RO**	13.9	$16.01	$1.28	$1,284,909	1220	445,300	512,986	27,648	540,634	733,370	1,157,390
MT0030643	SLEEPING BUFFALO HOT SPRINGS - LAGOON	***0.0129***	***Level 1***	**100% RO**	19	$0.25	$0.02	$19,667	1610	587,650	7,581	310	7,890	10,840	17,331
MT0030660	PINNACLE GAS RESOURCES - COAL CREEK DEVELOPMENT UNIT	***0***	***Level 1***	**100% RO**	19	$0.00	$0.00	$0	1610	587,650	0	0	0	0	0
MT0030724	FIDELITY - TONGUE RIVER PROJECT WTF	***2.44***	***Level 4***	**100% RO**	13	$31.72	$2.55	$2,545,295	980	357,700	872,788	58,560	931,348	1,313,142	2,153,090
MT0030741	HEADWATERS LIVESTOCK AUCTION	***0***	***CAFO***	**100% RO**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
MT0031411	WOLF MOUNTAIN COAL	***0.0048***	***Level 1***	**100% RO**	19	$0.09	$0.01	$7,318	1610	587,650	2,821	115	2,936	4,034	6,449
MT0031534	CATTLE DEVELOPMENT CENTER	***0***	***CAFO***	**100% RO**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
MT0031593	JAMES GUERCIO - OW RANCH	***0.19***	***Level 4***	**100% RO**	13	$2.47	$0.20	$198,199	980	357,700	67,963	4,560	72,523	102,253	167,659
MT0031623	IOFINA NATURAL GAS WATER TREATMENT FACILITY	***0***	***Level 5***	**100% RO**	6.5	$0.00	$0.00	$0	490	178,850	0	0	0	0	0
WERF															
Level	**Description**	**Capital Cost ($/gpd)**				**Operations ($1/ MG/day Treated)**						***0.08024***		***20 years, 5% rate***	
Level 1	No N and P removal	9.3				250									
Level 2	1 mg/l TP; 8 mg/l TN	12.7				350						20 years, 5% rate		0.08024	
Level 3	0.1-0.3 mg/l TP; 4-8 mg/l TN	14.4				640						20 years, 7% rate		0.09439	
Level 4	<0.1 mg/l TP; 3 mg/l TN	15.3				880									
Level 5	<0.01 mg/l TP; 1 mg/l TN	21.8				1370									
100% RO	<0.01 mg/l TP; 1 mg/l TN	**28.3**				**1860**									

Table A-2. Base Criteria Calculations 7%

NPDES ID	Facility Name	Flow (mgd)	Current Level of Nutrient Treatment	Required Level of Nutrient Treatment under the Criteria	Capital Cost per MGD ($million/ MGD)	Facility Upgrade Capital Costs ($million)	Annualized Capital Costs (Assumed 20 years, 7% rate; $million/year)	Annualized Capital Costs (Assumed 20 years, 7% rate; $/year)	Operations ($1/ MG/day Treated)	Operations Costs ($/ year/ 1 MGD)	Facility Upgrade Operations Costs (annual) based on Facility MGD	Membrane Replacement Cost ($24,000 /yr/1 MGD)*Actual Flow	Total Operations costs including membrane replacement	Total Operations costs including membrane replacement + Labor Low (15%)	Total Operations costs including membrane replacement + Labor Hi (48%)
MT0000264	CENEX HARVEST STATES COOP.	2.174	Level 1	*100% RO*	19	$41.31	$3.90	$3,898,994	1610	587,650	1,277,551	52,176	1,329,727	1,914,576	3,201,244
MT0000256	CONOCOPHILLIPS - BILLINGS REFINERY	2.66	Level 1	*100% RO*	19	$50.54	$4.77	$4,770,618	1610	587,650	1,563,149	63,840	1,626,989	2,342,582	3,916,886
MT0000019	BN WHITEFISH FACILITY	0.096	Level 3	*100% RO*	13.9	$1.33	$0.13	$125,958	1220	445,300	42,749	2,304	45,053	63,946	105,513
MT0000094	JOHN R DAILY INC	0.3	Level 3	*100% RO*	13.9	$4.17	$0.39	$393,619	1220	445,300	133,590	7,200	140,790	199,833	329,727
MT0000191	MONTANA RESOURCES	5.04	Level 4	*100% RO*	13	$65.52	$6.18	$6,184,624	980	357,700	1,802,808	120,960	1,923,768	2,851,462	4,892,388
MT0000230	MONTANA SULPHUR & CHEMICAL CO	3.28752	Level 3	*100% RO*	13.9	$45.70	$4.31	$4,313,429	1220	445,300	1,463,933	78,900	1,542,833	2,189,847	3,613,279
MT0000248	SIDNEY SUGARS INCORPORATED	1.3	level 1	*100% RO*	19	$24.70	$2.33	$2,331,505	1610	587,650	763,945	31,200	795,145	1,144,871	1,914,268
MT0000281	WESTERN SUGAR COOPERATIVE	9.36	level 1	*100% RO*	19	$177.84	$16.79	$16,786,838	1610	587,650	5,500,404	224,640	5,725,044	8,243,070	13,782,726
MT0000302	MDU - LEWIS & CLARK PLANT	42.43	Level 3	*100% RO*	13.9	$589.78	$55.67	$55,670,777	1220	445,300	18,894,079	1,018,320	19,912,399	28,263,015	46,634,372
MT0000388	MONTANA RAIL LINK -LIVINGSTON RAIL YARD	0.14256	Level 3	*100% RO*	13.9	$1.98	$0.19	$187,048	1220	445,300	63,482	3,421	66,903	94,961	156,686
MT0000396	CORETTE THERMAL PLANT	131	Level 3	*100% RO*	13.9	$1,820.90	$171.88	$171,880,078	1220	445,300	58,334,300	3,144,000	61,478,300	87,260,312	143,980,738
MT0000451	ASH GROVE CEMENT COMPANY	0.037728	Level 3	*100% RO*	13.9	$0.52	$0.05	$49,501	1220	445,300	16,800	905	17,706	25,131	41,466
MT0000477	EXXONMOBIL REFINING & SUPPLY	2.7	Level 1	*100% RO*	19	$51.30	$4.84	$4,842,357	1610	587,650	1,586,655	64,800	1,651,455	2,377,809	3,975,786
MT0000485	TRIDENT PLANT	0.0072	Level 2	*100% RO*	15.6	$0.11	$0.01	$10,602	1510	551,150	3,968	173	4,141	5,731	9,230
MT0000884	BIG SKY COAL COMPANY - BIG SKY MINE	3.045	Level 3	*100% RO*	13.9	$42.33	$4.00	$3,995,228	1220	445,300	1,355,939	73,080	1,429,019	2,028,303	3,346,728
MT0000892	DECKER COAL CO (WEST MINE)	1.12	Level 4	*100% RO*	13	$14.56	$1.37	$1,374,361	980	357,700	400,624	26,880	427,504	633,658	1,087,197
MT0020460	YELLOWSTONE BOYS & GIRLS RANCH	0.02	Level 1	*100% RO*	19	$0.38	$0.04	$35,869	1610	587,650	11,753	480	12,233	17,613	29,450
MT0021229	WESTMORELAND RESOURCES INC - ABSALOKA MINE	1.44	Level 3	*100% RO*	13.9	$20.02	$1.89	$1,889,369	1220	445,300	641,232	34,560	675,792	959,197	1,582,689
MT0021431	MT BEHAVIORAL HEALTH INC WWTP	0.1	level 1	*100% RO*	19	$1.90	$0.18	$179,347	1610	587,650	58,765	2,400	61,165	88,067	147,251
MT0023566	ELKHORN HEALTH CARE WWTP	0.015	level 1	*100% RO*	19	$0.29	$0.03	$26,902	1610	587,650	8,815	360	9,175	13,210	22,088
MT0023604	WESTMORELAND SAVAGE CORP - SAVAGE MINE	0.576	Level 3	*100% RO*	13.9	$8.01	$0.76	$755,748	1220	445,300	256,493	13,824	270,317	383,679	633,076
MT0023639	BOULDER HOT SPRINGS WWTP	0.085	Level 3	*100% RO*	13.9	$1.18	$0.11	$111,525	1220	445,300	37,851	2,040	39,891	56,619	93,423
MT0023965	WESTERN ENERGY CO - ROSEBUD MINE	0	Level 3	*100% RO*	13.9	$0.00	$0.00	$0	1220	445,300	0	0	0	0	0
MT0024210	DECKER COAL CO (EAST MINE)	0.89	Level 4	*100% RO*	13	$11.57	$1.09	$1,092,126	980	357,700	318,353	21,360	339,713	503,532	863,934
MT0024619	SPRING CREEK MINE	0.02	Level 3	*100% RO*	13.9	$0.28	$0.03	$26,241	1220	445,300	8,906	480	9,386	13,322	21,982
MT0024716	STILLWATER MINING COMPANY	0.94176	Level 4	*100% RO*	13	$12.24	$1.16	$1,155,641	980	357,700	336,868	22,602	359,470	532,816	914,178
MT0026808	STILLWATER MINING COMPANY	0.648	level 3	*100% RO*	13.9	$9.01	$0.85	$850,216	1220	445,300	288,554	15,552	304,106	431,639	712,210
MT0027821	BEAVERHEAD TALC MINE	0.10368	Level 1	*100% RO*	19	$1.97	$0.19	$185,947	1610	587,650	60,928	2,488	63,416	91,308	152,670
MT0028321	EXXON MOBIL BILLINGS REFINERY	5.86368	Level 1	*100% RO*	19	$111.41	$10.52	$10,516,308	1610	587,650	3,445,792	140,728	3,586,520	5,163,966	8,634,348
MT0028428	MONTANA TUNNELS MINING INC	0	level 5	*100% RO*	6.5	$0.00	$0.00	$0	490	178,850	0	0	0	0	0
MT0028584	LUZENAC AMERICA INC - YELLOWSTONE MINE	0	Level 3	*100% RO*	13.9	$0.00	$0.00	$0	1220	445,300	0	0	0	0	0
MT0028983	BULL MOUNTAIN MINE #1	0.36	Level 3	*100% RO*	13.9	$5.00	$0.47	$472,342	1220	445,300	160,308	8,640	168,948	239,799	395,672
MT0029891	BARRETTS MINERALS INC	1.5768	Level 3	*100% RO*	13.9	$21.92	$2.07	$2,068,859	1220	445,300	702,149	37,843	739,992	1,050,321	1,733,044
MT0029980	MONTANA AVIATION RESEARCH CO	0.05	Level 3	*100% RO*	13.9	$0.70	$0.07	$65,603	1220	445,300	22,265	1,200	23,465	33,305	54,954
MT0030015	M & W MILLING & REFINING INC	0.0216	Level 1	*100% RO*	19	$0.41	$0.04	$38,739	1610	587,650	12,693	518	13,212	19,022	31,806
MT0030031	ASARCO LLC - MIKE HORSE/ANACONDA MINE WATER TREATMENT SYSTEM	0.0468	Level 1	*100% RO*	19	$0.89	$0.08	$83,934	1610	587,650	27,502	1,123	28,625	41,215	68,914
MT0030066	COLUMBIA FALLS ALUMINUM CO	0.600905	Level 3	*100% RO*	13.9	$8.35	$0.79	$788,424	1220	445,300	267,583	14,422	282,005	400,268	660,448
MT0030147	ASARCO INC	0.136994	Level 3	*100% RO*	13.9	$1.90	$0.18	$179,745	1220	445,300	61,003	3,288	64,291	91,253	150,569
MT0030180	YELLOWSTONE ENERGY LIMITED PARTNERSHIP FACILITY	0.2494	Level 3	*100% RO*	13.9	$3.47	$0.33	$327,228	1220	445,300	111,058	5,986	117,043	166,128	274,113
MT0030279	MONTANORE MINERALS CORP MONTANORE MINE	0.01584	Level 5	*100% RO*	6.5	$0.10	$0.01	$9,719	490	178,850	2,833	380	3,213	4,671	7,878
MT0030350	REC ADVANCED SILICON MATERIALS LLC	1.152	Level 3	*100% RO*	13.9	$16.01	$1.51	$1,511,495	1220	445,300	512,986	27,648	540,634	767,358	1,266,151
MT0030392	M&K OIL COMPANY - WRIGHT CREEK WATER DISPOSAL FACILITY	0.0168	Level 3	*100% RO*	13.9	$0.23	$0.02	$22,043	1220	445,300	7,481	403	7,884	11,191	18,465
MT0030643	SLEEPING BUFFALO HOT SPRINGS - LAGOON	0.0129	Level 1	*100% RO*	19	$0.25	$0.02	$23,136	1610	587,650	7,581	310	7,890	11,361	18,995

Table A-2. Base Criteria Calculations 7%

NPDES ID	Facility Name	Flow (mgd)	Current Level of Nutrient Treatment	Required Level of Nutrient Treatment under the Criteria	Capital Cost per MGD ($million/ MGD)	Facility Upgrade Capital Costs ($million)	Annualized Capital Costs (Assumed 20 years, 7% rate; $million/year)	Annualized Capital Costs (Assumed 20 years, 7% rate; $/year)	Operations ($1/ MG/day Treated)	Operations Costs ($/ year/ 1 MGD)	Facility Upgrade Operations Costs (annual) based on Facility MGD	Membrane Replacement Cost ($24,000 /yr/1 MGD)*Actual Flow	Total Operations costs including membrane replacement	Total Operations costs including membrane replacement + Labor Low (15%)	Total Operations costs including membrane replacement + Labor Hi (48%)
MT0030660	PINNACLE GAS RESOURCES - COAL CREEK DEVELOPMENT UNIT	0	Level 1	***100% RO***	19	$0.00	$0.00	$0	1610	587,650	0	0	0	0	0
MT0030678	BARRETTS MINERALS - REGAL MINE	0.144	Level 3	***100% RO***	13.9	$2.00	$0.19	$188,937	1220	445,300	64,123	3,456	67,579	95,920	158,269
MT0030724	FIDELITY - TONGUE RIVER PROJECT WTF	2.44	Level 4	***100% RO***	13	$31.72	$2.99	$2,994,144	980	357,700	872,788	58,560	931,348	1,380,470	2,368,537
MT0030741	HEADWATERS LIVESTOCK AUCTION	0	CAFO	***100% RO***	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	0	**#N/A**	**#N/A**	**#N/A**
MT0031411	WOLF MOUNTAIN COAL	0.0048	Level 1	***100% RO***	19	$0.09	$0.01	$8,609	1610	587,650	2,821	115	2,936	4,227	7,068
MT0031534	CATTLE DEVELOPMENT CENTER	0	CAFO	***100% RO***	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	0	**#N/A**	**#N/A**	**#N/A**
MT0031593	JAMES GUERCIO - OW RANCH	0.19	Level 4	***100% RO***	13	$2.47	$0.23	$233,151	980	357,700	67,963	4,560	72,523	107,496	184,435
MT0031623	IOFINA NATURAL GAS WATER TREATMENT FACILITY	0	Level 5	***100% RO***	6.5	$0.00	$0.00	$0	490	178,850	0	0	0	0	0

WERF

Level	Description	Capital Cost ($/gpd)	Operations ($1/ MG/day Treated)		
Level 1	No N and P removal	9.3	250	***0.09439***	***20 years, 7% rate***
Level 2	1 mg/l TP; 8 mg/l TN	12.7	350		
Level 3	0.1-0.3 mg/l TP; 4-8 mg/l TN	14.4	640	**20 years, 5% rate**	**0.08024**
Level 4	<0.1 mg/l TP; 3 mg/l TN	15.3	880	**20 years, 7% rate**	**0.09439**
Level 5	<0.01 mg/l TP; 1 mg/l TN	21.8	1370		
100% RO	<0.01 mg/l TP; 1 mg/l TN	***28.3***	***1860***		

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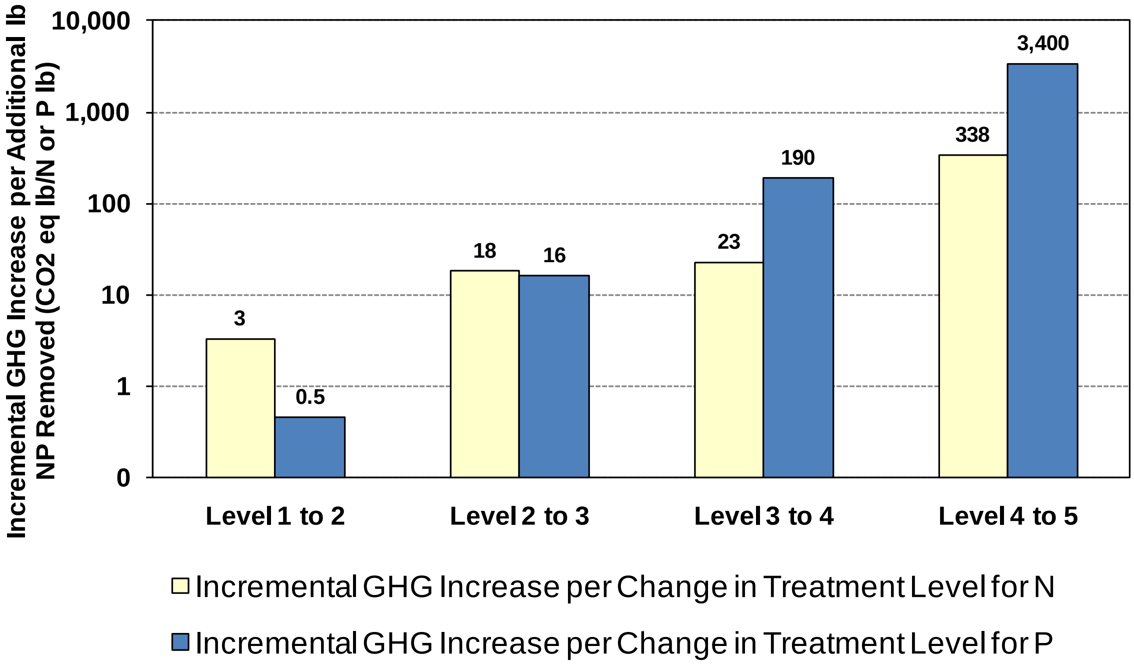
APPENDIX B - ASSUMPTIONS IN THE COST ANALYSIS

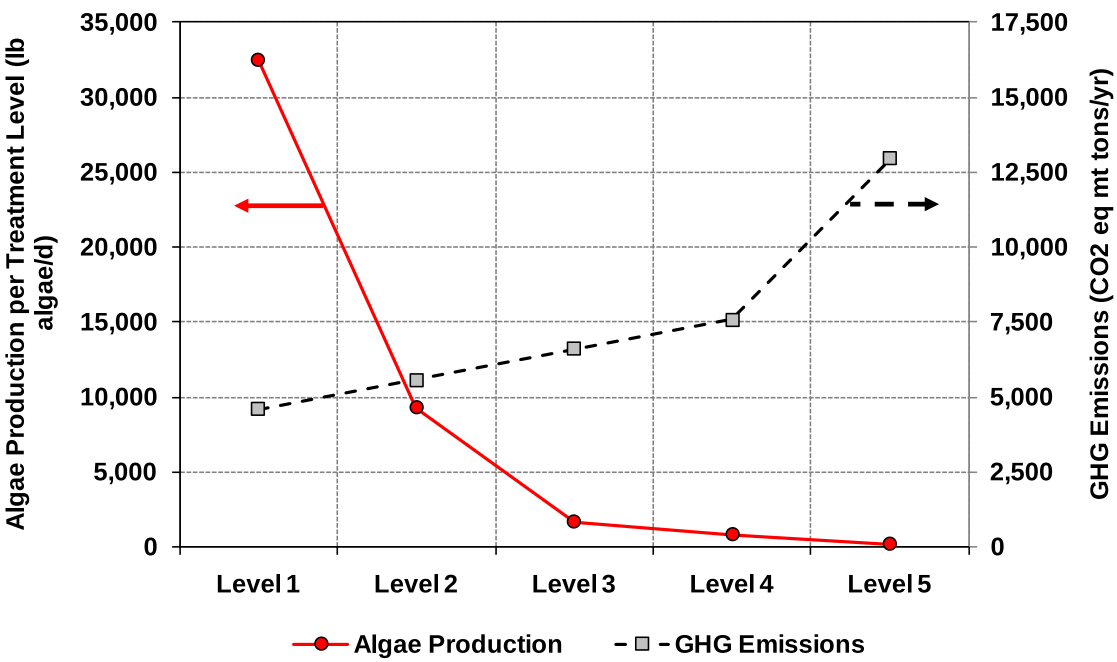
DESCRIPTION OF THE KEY CALCULATIONS/ DETAILS IN THE SPREADSHEET

- The spreadsheet numbers are intended to provide ROUGH ESTIMATES for discussion purposes and do not reflect the site-specific conditions at each plant.
- The cost estimates for upgrading WWTPs are obtained from the Interim WERF study: "Finding the Balance Between Wastewater Treatment Nutrient Removal and Sustainability, Considering Capital and Operating Costs, Energy, Air and Water Quality and More" (Falk, et al., 2011). This report is in Draft form and the capital costs are anticipated to increase in the final report based on feedback from the technical reviewers. Based on actual costs observed in EPA Region 1, Region 1 considered the capital costs to be higher than experienced in the final facility plan.
- Reverse osmosis is believed to be the technology that would allow WWTPs to have the best chance at meeting base numeric criteria at this time. It is ultimately assumed that 100% of wastewater would need to go through the reverse osmosis process to reach some Montana standards. Thus, the WERF cost estimate numbers for WERF Level 5 are increased using assumptions from adding RO.
- The design flows of new or upgraded wastewater plants at businesses would be the same as current flows, unless otherwise noted. This is a conservative assumption.
- Capital costs were assumed to cover a 10-year bond with 5% interest. An alternate assumption used a 7% interest rate.
- For the Montana businesses in this analysis with advanced treatment, the cost associated with the WERF level they are currently treating to is subtracted from WERF level 5 costs (plus 100% RO) in the study. That means that all businesses in our sample already at WERF level 2 will have the same estimated unit capital and O&M costs per MGD flow to meet base numeric criteria. Estimate total costs will differ based on facility flow.
- Operation costs in the WERF study, and therefore in this analysis, include energy and chemical costs only and do not include labor and maintenance cost. As such, the O&M cost numbers in this analysis are on the low side. An alternate assumption in the sensitivity analysis addresses this issue by adding labor costs.
- The costs in this demonstration do not include existing treatment plant abandonment, so they may underestimate total costs.
- Capital and O&M costs for businesses to get up to WERF 5 are based on building from scratch, assuming that no infrastructure exists.
- To get to RO, a membrane Replacement Cost is added which is estimated at $24,000/yr/1 MGD. Brine disposal costs are included within the WERF numbers.
- Design flow of a given business treatment plant was used to determine the capital costs and actual flow was used for the Operations costs. Flows for businesses were taken from wastewater permits.

APPENDIX C--NON MONETARY COSTS DISCUSSION

Source: DRAFT Interim WERF study "*Finding the Balance Between Wastewater Treatment Nutrient Removal and Sustainability, Considering Capital and Operating Costs, Energy, Air and Water Quality and More*" (Falk, et al., 2011).





Nearly 95 percent of the potential algae production is eliminated when changing from Levels 1 to Level 3 with a 44 percent increase in Green House Gas (GHG) emissions. An additional 4 percent of potential algae production (with respect to Level 1) is eliminated in Levels 4 and 5, while nearly doubling the GHG emissions (6,590 to 12,950 mt CO_2 equivalents/year).

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GHG emissions associated with chemical usage (production and distribution) at WWTPs are often overlooked. It is critical that the amount of GHG emissions associated with each individual chemical during production is incorporated into the evaluation. Several chemicals are mined in a few locations globally and the mining and transportation of the chemicals contribute to global GHG emissions. For example, the closest ferric mine to the United States is in Jamaica. For treatment plants located on the west coast, Jamaica is several thousand miles away and requires hauling. Additionally, the distance travelled, fuel type and truck fuel efficiency all play a role in quantifying their respective GHG emissions.

Recalcitrant dissolved organic nitrogen, commonly referred to as refractory dissolved organic nitrogen (rDON), impairs a WWTPs ability to reliably achieve low TN objectives. Effluent limits that require nitrogen values of 2 mg N/L or less might require the use of expensive and energy intensive strategies, such as reverse osmosis, that result in elevated GHG emissions.

Using reverse osmosis to achieve extremely low levels of nitrogen and phosphorus increases costs and GHG emissions. Brine reject management remains a challenge for reverse osmosis applications, especially for inland applications.

APPENDIX D-RO LITERATURE

Source: Tetratech, Alejandro Escobar

REVERSE OSMOSIS EFFICACY FOR TN REMOVAL

Bench, pilot, and full-scale studies describing Reverse Osmosis (RO) treatment to very low Total Nitrogen (TN) levels were obtained and summarized. The Montana Draft Nutrient Criteria are proposed to be between 0.3-1.2 mg/L TN depending on Level III Ecoregion.

The nitrogen removal capabilities described in these studies are described in **Table D-1** and more detailed descriptions of the studies reviewed are provided following **Table D-1**. Species of nitrogen removal rates are also included as percentages in **Table D-1**. Merlo et al. (2011) noted that organic nitrogen may not be reliably removed by RO treatment. The data provided in **Table D-1** are generally average (mg/L) values and the percentages listed are removal rates. Studies do not always report influent conc., effluent conc., and percent removal for all nitrogen species. Associated cost data was most often not available, but when available it was included in **Table D-1**.

A number of studies have been done on facilities with low influent concentrations of TN, especially after pretreatment by various means including biological nutrient removal, microfiltration, ultrafiltration, and other standard wastewater treatment processes.

Table D-1 also includes information obtained from RO technology manufacturers. Five manufacturers were contacted via e-mail and responses were received from two of the manufacturers: CSM Filters and Pure Aqua, Inc. The nitrogen rejection by Pure Aqua, Inc. filters was said to be highly variable and the manufacturer did not provide specific concentrations other than ranges of nitrogen removal. The CSM Filter data is summarized in **Table D-1** below.

A number of factors may influence the reliability of RO in meeting criteria. Studies generally listed average values without any reliability data. Removal of dissolved nitrogen species is dependent on the initial concentrations in the influent and characteristics of the wastewater. Very high and very low TDS, temperature, pH and may impact some membrane's nitrogen removal properties. Also some variability in RO efficacy in nitrogen species removal is seen from site to site and as a result of differing pretreatment processes prior to RO. Membrane rejection values can only be guaranteed after the RO process has been defined.

A 2-pass RO system for wastewater treatment is quite expensive to operate according to a CSM Filter representative, who was not aware of many applications of 2-pass systems in practice for TN removal. Some studies from the literature indicated arrays of membranes including a mixture of nanofiltration and RO (Drewes, et al., 2005; Ushikoshi, et al., 2002) or Forward Osmosis and RO (Cath, et al., 20006).

International studies are included in **Table D-1** from countries such as Norway, Poland, Australia, Finland, China, Czech Republic, South Africa, Japan, and France. Both industrial and municipal wastewater streams were also included.

Table D-1. Summary of studies describing Reverse Osmosis treatment and Nitrogen species removal results[7]

Source	Type	Location	Effluent Type	Description	TN	NH_3-N	NO_3	NO_2	TKN	N_{org}	Cost
Bilstad 1995	Pilot	Norway	Mixture of municipal and industrial wastewater (wool scouring)	Tubular RO membrane	Inf: 24.1-33.5 Eff: 0.8-2.2 94-97%	Inf: 15.3-29.5 Eff:0.5-1.3	Inf: 0-10 Eff: 0-0.5		-	-	2x$ as BNR
Bohdziewicz 2005	Bench-scale	Swine Processing Plant Uni-Lang – Wrzosowa, Poland	Industrial - Meat processing plant	High pressure membrane (SEPA CF-HP)	Inf: 13 Eff: 1.3 90.0%	-	-	-	-	-	NA
Cath 2006	Full-scale	Coffin Butte Landfill – Corvallis, OR	Industrial – Landfill leachate	One FO membrane and four RO membranes	-	Inf: 1110 Eff: 1.6 99.9%	-	-	Inf: 780 Eff: ND 100%	-	NA
Drewes 2005	Pilot	West Basin WRP – Segundo, CA	Not nitrified micofiltered secondary wastewater effluent	Low pressure membranes Toray TMG-10 Dow NF-90	-	Inf:31.5 (est) Eff: 1.2 Inf:37.4 (est) Eff:2.3	Inf: <1 mg/L Eff: ND Eff: ND	-	-	-	NA
Ghayeni 1998	Pilot	Sydney, Australia	Secondary municipal wastewater w/ biological nutrient removal	Two membranes Film Tec - NF45 Fluid Systems - TFCL	-	No measureable amount of ammonia in Inf or Eff	Inf: 0.37 (BOTH) Eff:0.3 Eff:0.2		-	-	NA
Häyrynen 2008	Bench-scale	Gold Mine - Finland	Industrial – Gold mine effluent	Four RO membranes Filmtec SW30HR HydranauticsESPA2 KOCH TFC ULP Sepro – RO1	-	Inf: 9.53 Eff: 1.64 82.8% Eff: 0.54 94.3% Eff:0.81 91.5% Eff:0.80 91.6%	Inf: 15.6 Eff: 0.94 93.9% Eff: 0.40 97.4% Eff:0.36 97.7% Eff:0.61 96.0%	-	-	-	0.31-0.34 Euro/m^3 for plant capacities of 250,000 m^3 and 1,000,000 m^3
Häyrynen 2008	Bench-scale	Chromite Mine - Finland	Industrial – Chromite mine effluent	Four RO membranes Filmtec SW30HR HydranauticsESPA2 KOCH TFC ULP Sepro – RO1	-	Inf: 5.50 Eff: 0.86 84.4% Eff: 0.33 94.0% Eff:0.60 89.1% Eff:0.60 89.1%	Inf: 20.8 Eff: 1.66 92.0% Eff: 1.33 93.6% Eff:1.94 90.7% Eff:0.89 95.7%	-	-	-	0.31-0.34 Euro/m^3 for plant capacities of 250,000 m^3 and 1,000,000 m^3
Häyrynen 2008	Bench-scale	Phosphate Mine - Finland	Industrial – Phosphate mine effluent	Four RO membranes Filmtec SW30HR HydranauticsESPA2 KOCH TFC ULP Sepro – RO1	-	Inf: 11.8 Eff: 1.07 90.9% Eff: 0.65 94.5% Eff:0.82 93.0% Eff:1.64 86.1%	Inf: 44.0 Eff: 1.17 97.3% Eff: 1.76 96.0% Eff:2.68 93.9% Eff:3.05 93.1%	-	-	-	0.31-0.34 Euro/m^3 for plant capacities of 250,000 m^3 and 1,000,000 m^3

[7] Nitrogen species values are average mg/L values unless otherwise noted. The percentages provided are removal percentages. When multiple RO processes or filters were tested in a study, they are all listed in **Table D-1** in separate rows.

Table D-1. Summary of studies describing Reverse Osmosis treatment and Nitrogen species removal results[7]

Source	Type	Location	Effluent Type	Description	TN	NH_3-N	NO_3	NO_2	TKN	N_{org}	Cost
Huang 2011	Bench-scale	Iron and Steel Manufacturer - China	Industrial – Iron and Steel Manufacturer mixed effluent	Two treatment processes UF/RO process CW/UF/RO process	-	Inf: 1.82 Eff: 0.11 94.0% Inf:0.40 Eff:ND 100%	-	-	-	-	NA
Merlow 2011	Pilot	HAARF treatment plant - Escondido, CA	Municipal wastewater	Toray TML-10 membrane	Inf: 19.4 Eff: 1.88 91.0%	Inf: 8.78 Eff: 0.61 91.8%	Inf: 6.57 Eff: 0.45 94.5%	Inf: 2.17 Eff: 0.19 89.4%	Inf: 10.8 Eff: 1.22	Inf: 1.97 Eff: 0.61 68.2%	NA
Merlow 2011	Full-scale	GWRS – Fountain Valley, CA	Secondary Municipal wastewater	Hydranautics ESPA2 membrane	-	Inf: 21.0 Eff: 1.24 93.3%	-	-	Inf: 23.0 Eff: 1.32	Inf: 2.03 Eff: 0.10 94.4%	NA
Merlow 2011	Full-scale	Vander Lans AWTF – Southern CA	Tertiary Municipal wastewater	Hydranautics ESPA2 membrane	Inf: 8.91 Eff: 1.47 89.5%	Inf: 1.07 Eff: 0.17 81.2%	Inf: 5.85 Eff: 1.22 89.8%	Inf: 0.08 Eff: 0.06 26.3%	-	Inf: 1.91 Eff: <0.2 93.5%	NA
Merlow 2011	Full-scale	Scottsdale Water Campus AWTF – Scottsdale, AZ	Municipal wastewater	RO	-	Inf: 0.88 Eff: 0.16 78.6%	-	-	-	Inf: 1.05 Eff: 0.14 80.7%	NA
Merlow 2011	Pilot	Miami-Dade County, FL	Municipal wastewater	Six RO pilot processes CSM Koch Toray Dow Hydranautics Hydranautics	No Influent Effluent 1.49 1.51 2.01 2.30 1.81 2.67	-	-	-	-	No Influent Effluent 0.34 0.32 0.38 0.54 0.39 0.66	NA
Merlow 2011	Pilot	Luggage Point AWTF – Queensland, Australia	Municipal wastewater	Toray TML-4040 membrane	88%	83%	87%	94%	88%	92%	NA
Merlow 2011	Pilot	Bureau of Reclamation	Municipal wastewater	Dow RO (BW30-4040) membrane	-	Inf: 0.79 Eff: 0.20	Inf: 8.46 Eff: 0.47	-	Inf: 1.55 Eff: 0.30	Inf: 0.76 Eff: 0.10 86.6%	NA
Merlow 2011	Pilot	City of San Diego, CA	Municipal wastewater	Dow RO (BW30-4040) membrane	-	-	-	-	-	No Influent Eff: <0.18-0.25	NA
Šir 2011	Pilot	Landfill in northern Bohemia, Czech Republic	Industrial – Hazardous Landfill Leachate	Filmtec SW30-4040 membrane	-	Inf: 142 Eff: 8.54 94.0%	Inf: 0.83 Eff: 0.04 95.2%	-	-	-	NA
Schoeman 2003	Full-scale	South Africa	Groundwater treatment for drinking water	Delta 4040-LHA-CPA2 membrane	-	-	Inf: 42.46 Eff: 0.85 98.0%	-	-	-	Capital: $29,900 Op: $0.50/m^3 for a 50 m^3/d output
Ushikoshi 2002	Full-scale	Landfill in Japan	Industrial – Landfill Leachate	High Pressure 2-stage RO/NF	Inf: 12.9-164 Eff: <1-2 92.2-98.9%	Inf: 3.9-53 Eff: 0.29-1.53 90.2-98.4%	-	-	-	-	-
Vourch 2008	Bench-scale	France	Industrial – Wastewater from three Dairy Farms	KOCH TFC HR SW 2540 membrane	-	-	Eff: <2	-	96.1%	-	NA
Qin 2005	Pilot	Coconut Island, Hawaii	Industrial – Aquaculture Wastewater	Flimtec XLE-4040 membrane	94.7%	Eff:<0.05	Eff:<0.03	Eff:<0.003	-	-	$4.00/m^3 permeate

Table D-1. Summary of studies describing Reverse Osmosis treatment and Nitrogen species removal results[7]

Source	Type	Location	Effluent Type	Description	TN	NH_3-N	NO_3	NO_2	TKN	N_{org}	Cost
CSM Filter	Full-scale	Orange County, CA	Municipal wastewater	RO	Inf: 12.5 Eff: 0.7 96.3%	Inf: 1.0 Eff: 0.3 78.6%	Inf: 11.4 Eff: 0.35 97.9%	Inf: 0.09 Eff: <0.002 99.1%	Inf: 1.0 Eff: 0.3 81.3%	-	Cap: $481M. (70 mgd plant). $600 acre/foot (total process)
CSM Filter	Full-scale	Los Angeles, CA	Municipal wastewater	RO	-	Inf: 36.0 Eff: 2.4 93.3%	Inf: 2.36 Eff: 0.41 82.6%	Inf: 6.97 Eff: 0.69 90.1%	-	-	NA
CSM Filter	Full-scale	Richmond, CA	Municipal wastewater	RO	-	Inf: 0.98 Eff: 0.3 89.6%	Inf: 24.0 Eff: 1.5 98.4%	Inf: 0.013 Eff: 0.0025 97.1%	Inf: 1.4 Eff: 1.0 71.4%	-	NA
CSM Filter	Bench-scale	Anaheim, CA	NA	FE – low fouling BE – brackish BLR – low pressure HUE – High TOC	97.6% 98.1% 97.5% 98.3%	98.2% 98.5% 98.0% 98.7%	88.0% 93.1% 89.5% 94.7%	88.8% 93.1% 89.5% 94.3%	-	-	NA

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STUDY SUMMARIES

Bilstad, T. 1995. Nitrogen separation from domestic wastewater by reverse osmosis.

Norwegian pilot-scale study of nitrogen removal using spiral-wound membranes and tubular membranes for RO. Results were only included for the Tubular membrane output. Three separate runs of the treatment setup were completed with the results summarized in **Table D-1**. Treatment costs using membrane separation by RO were noted to be twice as expensive as biological nutrient removal (BNR). Tubular membranes are considered unrealistic for high-volume influent such as that in domestic wastewater for nitrogen removal due to high costs.

Bohdziewicz, J. and E. Sroka. 2005. Integrated System of activated sludge-reverse osmosis in the treatment of the wastewater from the meat industry.

This study used samples from a swine processing facility in southern Poland to test the efficacy of a hybrid system of combining the biological methods of activated sludge in an SBR and reverse osmosis. Initial effluent was TN 198 mg/L, 13 mg/L after pretreatment with SBR, and 1.3 mg/L after RO process.

Cath, T.Y. et al. 2006. Forward osmosis: Principles, applications, and recent developments.

This paper reviewed a number of applications of osmosis or forward osmosis, many of which did not have applicable results for nitrogen. However, the Coffin Butte Landfill in Corvallis, OR did have results for nitrogen. RO treatment at the landfill started as a pilot project to treat landfill leachate and as a result of the success of the treatment became full-scale in 1998. A combination of traditionally used RO through four filters (Osmonics-CE, Osmonics-CD, Hydranautics-LFC1, and Hydranautics-LFC3) and forward osmosis (FO) through a CTA-Osmotek filter were used to treat most contaminants to greater than 99% rejection.

Drewes, J.E. et al. 2005. Can Nanofiltration and Ultra-low Pressure Reverse Osmosis Membranes Replace RO for the Removal of Organic Micropollutants, Nutrients, and Bulk Organic Carbon? – A Pilot-scale Investigation.

This pilot-scale study was a low pressure nanofiltration (NF) and ultra-low pressure reverse osmosis (ULPRO) pilot study run at the West Basin Water Recycling Plant in Segundo, California, a water reuse facility. Two lower pressure membranes were tested on the pilot-scale skid: a Toray TMG-10 (ULPRO) and a Dow NF-90 (NF). Results indicated that nitrogen species, along with other contaminants, could be removed to levels comparable to traditional RO processes using these low pressure filters.

Ghayeni, S.B.S. et al. 1998. Water reclamation from municipal wastewater using combined microfiltration-reverse osmosis (ME-RO): Preliminary performance data and microbiological aspects of system operation.

Two membranes, a traditional RO membrane and a nanofiltration membrane, were studied on a pilot-scale analysis at a wastewater treatment plant in Sydney, Australia. The pretreatment process included an activated sludge process with biological nitrogen and phosphorus removal and microfiltration prior to the RO treatment, so nutrient levels were already very low prior to RO. Prior to RO Ammonia levels were ND and NOx levels were already very low at 0.37. Phosphate levels were at 3.5 mg/L, and both filters reduced the levels to ND (reported as 0). The RO filters used in the pilot study were a Fluid Systems TFCL (cross-linked aromatic polyamide, thin-film composite) and a Film Tec NF45 membrane (nanofiltration, polypiperazine amide, thin-film composite).

Häyrynen, K. et al. 2008. Separation of nutrients from mine water by reverse osmosis for subsequent biological treatment.

This study examined the treatment capabilities for nutrient removal on three different mines in Finland. First a bench-scale analysis was done testing the capabilities of four different membranes (Filmtec SW30HR, Hydranautics ESPA2, KOCH, TFC ULP, Sepro RO1). In addition a pilot-scale analysis was performed using the Sepro membrane and effluent from the Gold and Chromite mines, but nutrient removal results were not reported. Cost data were included including a breakdown for two plant capacities (250,000 m3 and 1,000,000 m3) by energy, chemicals, membranes, labor, and capital costs (calculations in Euro).

Huang, X. et al. 2011. Advanced treatment of wastewater from an iron and steel enterprise by a constructed wetland/ultrafiltration/reverse osmosis process.

This study evaluates the effectiveness of two different treatment processes at filtering contaminants from the Baosteel iron and steel manufacturing plant. The two treatment processes were an UF/RO: ultrafiltration system followed by a reverse osmosis process and CW/UF/RO: a constructed wetland, followed by the ultrafiltration system and the reverse osmosis process. The RO membrane tested in both cases was a Filmtec BW30FR-based polyamide composite membrane.

Merlow, R. et al. 2011. Analysis of Organic Nitrogen Removal in Municipal Wastewater by Reverse Osmosis.

A synthesis of pilot-scale and full-scale case studies on various treatment processes and capabilities of nitrogen species removal using RO. Facility process descriptions and methods are summarized. Primary sources were not obtained at this time.

Šir, M. et al. 2011. The effect of humic acids on the reverse osmosis treatment of hazardous landfill leachate.

The potential for RO treatment at an abandoned brown coal pit in northern Bohemia, Czech Republic was evaluated. A pilot-scale study treated the landfill leachate with very minimal pretreatment by running the leachate through a Filmtec SW30-4040 membrane. The first stage concentrate was additional run through another RO membrane to further concentrate the contaminants. It was noted that ammonia nitrogen was the only indicator that still exceeded limits in the permeate and subsequent study of ammonia removal methods is needed.

Schoeman, J.J. and A. Steyn. 2003. Nitrate Removal with reverse osmosis in a rural area in South Africa.

Due to high nitrate-nitrogen and salinity levels in boreholes in South Africa, a RO plant was built to produce safe drinking water. This study examines results from this facility. A Delta 4040-LHA-CPA2 membrane was used with sand filters as a pretreatment step. Cost estimates were provided for this system including capital costs of $29,900 for a 50 m^3/day output RO plant with operational costs for denitrification of $0.50/m^3.

Ushikoshi, K. et al. 2002. Leachate treatment by the reverse osmosis system.

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A bench-scale analysis of wastewater treatment from three dairy farms in France was summarized. A RO spiral-wound membrane (KOCH TFC HR SW 2540) to treat samples from the farms.

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This study summarizes the results of a pilot-study to treat aquaculture wastewater with a wind-driven RO system on Coconut Island, HI. The process included a cartridge filter as pretreatment before the spiral wound Filmtec XLE-4040 membrane. Detailed cost estimates are provided that indicate a relatively high $4.00/ 1m^3 permeate cost for the pilot study. However if scaled up to between 9000-13200 m^3/year (currently between 1500-2200 m^3/year), it is anticipated unit costs would drop to between $1.11-$1.62/m^3 permeate.

MANUFACTURERS CONTACTED

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